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ERRATA AND AUTHORS' EMENDATIONS

Page 8, fifth line from bottom, "Red Indian" should be "Hidatsa Red."
Page 48, Table 5, third column, line 3, "42" should be "47"; line 4, "46" should be "45."
Page 180, fifth line from bottom, "502" should be "500"; and second line from bottom, "500" should be "502."
Page 272, Table 4, line 1, under No. 13, "+2=2" should be "+2+2."
Page 282, sixteenth line from bottom, "Seventy-three" should be "Seventy-five."
Page 323, line 17, "Figure 1, B" should be "Figure 1, C."
Page 328, twenty-second and twenty-third lines from bottom, "(pl. 2, A)" should be "(fig. 1, C)."
Opposite page 332, legend for Plate 6, line 7, "(fig. 3, B)" should be "(fig. 2, B)'; line 8, "Figure 3, A" should be "Figure 2, A."
Page 333, line 21, "(p. 65)" should be "(p. 325)."
Page 426, Plate 5 should be turned 180 degrees.
Page 443, the female formula should be: *Female.* $\frac{0.5\ \ 3.5\ \ 4.1^{78}\cdot 82.^{16}\cdot 99.0}{0.4\ \ 0.8\ \ 0.8\ \ \ \ 1.2\ \ \ 0.9}$ 2.4 mm.
Page 456, Table 3, column 2, under CO_2, "*a*5–47" should be "*a*35–47"; last line of text, "starch" should be 'polysaccharides."
Page 618, Figure 5, B, "*st*" should have been inserted in the upper left-hand corner.
Page 619, legend for Figure 6, D, last line, "350" should be "467."
Page 628, seventh line from bottom, "form" should be "farm."
Page 682, Table 2, mean phosphorus efficiency factor for the series 020-021-022-024 in sixth column under Green sweet corn, "18.10±2.0," should be "18.10±2.2."
Page 688, Table 4, potash efficiency factor for treatment 112, "27.63±6.3," should be "27.63±6.4."
Page 691, Table 5, nitrogen efficiency factor for treatment 122 under Edible green sweet corn, "25.95±9.8," should be "25.95±9.3."
Page 696, Table 7, under Green sweet-corn fodder, the mean increase in yield for the series 012-112-212-412, "23.79±27," should be "23.79±2.7."
Page 702, second line of last paragraph, formula in parenthesis "(7.5-5-64-50)" should be "(7.5-64-50)."
Page 706, second line from bottom, insert "local" between "the" and "reactions."
Pages 714 and 715, footnotes to Tables 5 and 6, reference marks "*e*" and "*c*" should be reversed.
Page 721, heading for Table 9, "a virulent" should be "an avirulent."
Page 724, twenty-first line from bottom, insert "to" between "*abortus*" and "bovine."

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A CLASSIFICATION OF THE VARIETIES OF FIELD BEANS, PHASEOLUS VULGARIS [1]

By F. H. STEINMETZ, formerly *Assistant Agronomist*, and A. C. ARNY, *Associate Agronomist, Minnesota Agricultural Experiment Station*

INTRODUCTION

Several classifications of both European and American varieties of field beans are available, but up to the present none deal specifically with species of Phaseolus and varieties of *P. vulgaris* L. grown for their dry edible seeds. The field-bean-growing sections are somewhat localized in the New England, the North Central, and the Pacific Coast States ranging from Oregon to southern California and Arizona. Since the range in climate between any two extremes of the above-mentioned sections is wide, it follows that varieties grown in one extreme are not always adapted to another. The choice of a variety adapted to local conditions affects directly the yield and profitableness of the crop; hence the choice of a variety for a given locality merits careful consideration. However, in order to be able to make this choice, the identity of types and varieties must be established with certainty. There is need, therefore, for a classification of field varieties by the use of which the identity of the varieties may be definitely established. It is the purpose of this study (1) to determine a practical basis for the classification of field varieties of common beans, (2) to construct a key based largely upon characters that are stable under varying climatic conditions so that it may be of value wherever beans are grown, and (3) to describe the varieties as found when grown in the environment of University Farm, St. Paul, Minn.

REVIEW OF LITERATURE

Von Martens (*10*) [2] published his second revised classification of garden beans in 1869. He did not distinguish garden beans from field beans. In his classification the common beans (*Phaseolus vulgaris*) are separated into seven species according to the shape of the seed. A secondary division is based upon the color of the seeds.

In 1865 Burr (*3, p. 434–481*) described 56 varieties of *Phaseolus vulgaris*. Eight of these appear to be field varieties recognized at present.

Irish (*7*) described all obtainable varieties from cultures grown at the Missouri Botanical Garden in 1901. His key to varieties is based primarily on the form and color of the seed. For secondary divisions he uses plant and immature pod characters.

The use of dry seeds and green pods is impractical for the reason that the immature pods can not be stored conveniently for future use in identification. The reliability of absolute measurements may, at least, be questioned. However, the combined use of seed, pod, and type of plant is a step toward what undoubtedly will become a

[1] Received for publication Dec. 28, 1931; issued August, 1932. Paper No. 1070 of the Journal Series of the Minnesota Agricultural Experiment Station.

[2] Reference is made by number (italic) to Literature Cited, p. 49.

comprehensive basis for the identification of varieties. Irish states that the variety Navy is largely grown as a field crop.

In 1907 Tracy (*13*) described American varieties of garden beans, Phaseolus, within three species—*vulgaris*, *lunatus*, and *multiflorus*. His major divisions are based upon plant habit and character of green pod. A secondary division is based upon form, size, and color of the dry seed. He includes varieties of field beans. In his key the varieties of field beans are set apart according to texture of the green pod.

Tracy has made a fairly clear distinction between field and garden varieties of common beans based upon the texture of the green pods. However, when this comparison is extended to the dry mature pod the distinction becomes more apparent. Dry pods of field beans are fibrous and dehisce at the sutures, while the dry pods of good varieties of garden beans are brittle, contain relatively little fiber, and break in cross section rather than dehisce at the sutures during threshing. The terms "thick stemmed" and "thin stemmed" are too indefinite to be of value in placing plants with stems intermediate in thickness. Tracy refers specifically to 12 varieties as field beans in his descriptions.

Jarvis (*8*) described American varieties of beans, which he separated into three species of the genus Phaseolus and four other genera—Vicia, Vigna, Dolichos, and Glycine. He utilizes color and form of seed, but bases his major classification upon size of seed and the ratio of the length to the width. In his descriptions he groups varieties of Phaseolus according to the type of the plant and the pods.

In the exclusive use of seed characters for the classifications of varieties Jarvis makes many distinctions so minute as greatly to lessen the practical usefulness of his key. The combined use of seed, dry pod, and plant habit in a key would appear to facilitate greatly the identification of varieties. In his key he makes no separation of garden varieties and field varieties. However, in his descriptions he points out whether a variety is suited for green-pod or for dry-shell purposes. He refers specifically to 21 varieties as field types.

In 1912 Freeman (*5*) described six native field varieties of *Phaseolus vulgaris*, namely, Pink, Bayou, Hansen, Garaypata, Red Indian, and Mottled Red Indian. In addition, he first describes the tepary bean, *P. acutifolius* var. *latifolius* as a new field species. There is incorporated a detailed discussion of the origin of this new species. He concludes that it is a native of the southwestern part of the United States or Mexico. He adopts the name "tepary," which the Mexicans use to distinguish it from the common "frijole" or kidney bean. Three varieties of "teparies" are described, but he states that as many as 49 distinct forms are recognized.

In 1912 Hendry (*6*) described 16 varieties of field beans adapted to California, representing four genera—Vigna, Vicia, Cicer, and Phaseolus. He gives the history and the adaptation of the varieties described.

In 1919 Chittenden (*1*) grew 253 stocks of beans of which 224 are described as dwarf or nonclimbing types. The remaining 29 climbers or semiclimbers are not described.

The method used is undoubtedly valuable as a convenience to growers and seed producers but is limited in usefulness because flowers and green pods are available only during a part of the growing season.

MATERIALS AND METHODS

As early as 1914 a collection of seed of varieties of field beans was begun. Seed from the bean-growing sections of the United States and Canada was obtained through seed houses, growers, and experiment stations. An effort was made to obtain seed of the main varieties grown in each of the bean-growing sections of the United States, namely, the New England, north central, Pacific coast, and southwestern sections. In addition, a few samples were obtained from Sweden and France. The growing of these varieties began in 1915. Intensive work toward isolating types began with the harvesting of the 1918 crop.

From the beginning the beans were planted in rows 18 feet long and 2 feet apart with one seed dropped every 3 inches. In order to fix the type for a given variety, commercial seed was planted in rows as described above. At harvest time typical and nontypical plants were selected and the seed planted in progeny rows for observation and increase. The rows having plants which were the most representative of a certain variety were chosen as the type. Other rows representing other types in the original sample were continued if they were sufficiently distinct. From the type rows the one showing the best performance record was increased, given a Minnesota number, classified, and described.

It is recognized that some natural crossing occurs in beans when varieties are grown near each other. The only effort made to control the effects of this was to rogue out plants which varied from the selected type.

During three years of the study, when it was possible, 100 pods were selected from the various types at harvest time and stored in small pasteboard boxes. These pods were measured, the length and width of pod and the length of spur being taken. From the same material the number of seeds per pod was determined and the three dimensions of 100 seeds were obtained. The weight per 1,000 seeds was determined from the bulk of the seed which was harvested from each row or plot. The seeds were counted into two lots of 500 each for weighing.

Weights and measurements of the seeds of varieties are given in Tables 1–4, inclusive.

EFFECT OF ENVIRONMENT UPON SIZE OF SEED

Among the factors affecting the size of the seed are temperature, moisture, productivity of the soil, rate, and date of planting.

Freeman (*5*), Jarvis (*8*), and Hendry (*6*) use size of seed in their descriptions of varieties and they report the measurements of three dimensions. Zavitz (*14*) and Freeman (*5*) give weight of seed as a descriptive character. A summary of the measurements and weight of seed reported for a few varieties of beans grown in different localities is shown in Table 1. By comparing the measurements recorded it will be seen that marked variations occur. For example, the length of seeds in different years for the variety Red Kidney ranges from 1.8 cm in New York to 1.4 cm in California. The weight per 1,000 seeds for different years as reported by Zavitz and by the present writers for the variety Red Kidney shows a wide variation in size. A study of this table indicates that a classification based mainly upon size of seed may well be questioned, except possibly for a particular locality.

TABLE 1.—*Measurements of length, width, and thickness of seeds and weight per 1,000 seeds of certain bean varieties reported from various localities*

Variety	Weight per 1,000 seeds in—			Length, width, and thickness of seeds in—			
	Ontario, 1915	Arizona, 1912	Minnesota, 1920	New York, 1908	Arizona, 1912	California, 1918	Minnesota, 1920
	Grams	*Grams*	*Grams*	*Centimeters*	*Centimeters*	*Centimeters*	*Centimeters*
Pearce Improved Tree	436.6		331.0				1.159 by 0.746 by 0.478
Red Kidney	513.1		390.9	1.8 by 1.0 by 0.65		1.41 by 0.82 by 0.60	1.539 by .701 by .542
Improved Yellow Eye	462.1		338.1	1.25 by .8 by .7			1.106 by .685 by .604
Hansen		230.0	237.3		1.15 by 0.68 by 0.48		1.116 by .709 by .469
Garaypata		230.0	266.8		1.11 by .68 by .40		1.191 by .703 by .480
Hidatsa Red		210.0	301.2		1.13 by .68 by .48	1.08 by .72 by .49	1.157 by .744 by .500
Black Turtle Soup			199.4	1.15 by .7 by .45			1.044 by .599 by .402

It was arranged to have some of the bean varieties grown at outlying stations in Minnesota; that is, at Crookston, Grand Rapids, Duluth, Coon Creek, and Radisson. By the use of the seed produced at these locations a study was made of the effect of environment upon size. From the results given in Table 2 it is evident that for two varieties grown in 1920 there is a wide variation in the size of the seed. Robust beans were approximately 40 per cent smaller by weight grown on peat at Radisson [3] than at Grand Rapids on a sandy loam. The difference is not so marked between any other two localities, but it is great enough to make it questionable whether a useful classification of Robust beans for different localities or environments can be based upon the size of the seed. The seed of the variety Improved Goddard grown at Crookston is approximately 30 per cent by weight less than seed grown at Grand Rapids. The above evidence indicates that the size of the seed produced from the same varieties is materially affected by the locality in which it is grown.

At University Farm, St. Paul, Minn., some work was done upon rate and date of planting. The results are given in Table 3. The seeds produced in 1920 from Robust 76 beans planted late are smaller in size than those planted at the regular time, and those spaced far apart in rows are larger than those planted close. For example, Robust beans planted May 12 weighed 233 g per 1,000 and those planted May 22 weighed 212 g per 1,000, while the late planting, June 22, weighed 204 g per 1,000. It appears, therefore, that date of planting influences the size of seed produced. The other factor, rate of planting, gave similar results. Robust beans planted 4 inches apart in rows produced seed weighing 218 g per 1,000, while beans planted 8 inches apart produced seed weighing 244 g per 1,000.

TABLE 2.—*Variation in size of seed of beans of two varieties grown in different localities in 1920*

Variety	Locality	Length of seed	Width of seed	Thickness of seed	Ratio			Thickness, width factor	Weight per 1,000 seeds
					Length	Width	Thickness		
		Centimeters	*Centimeters*	*Centimeters*					*Grams*
Robust No. 76	University Farm	0.840	0.584	0.480	1	0.695	0.571	0.822	176.8
	Duluth	.849	.625	.508	1	.736	.598	.813	185.8
	Crookston	.893	.651	.539	1	.739	.603	.828	205.2
	Grand Rapids	.872	.682	.564	1	.782	.647	.827	236.2
	Coon Creek, sand	.840	.577	.452	1	.687	.539	.783	157.4
	Radisson, peat	.785	.569	.446	1	.725	.568	.787	133.0
Improved Goddard No. 139.	Duluth	1.603	.798	.593	1	.498	.369	.743	529.0
	Crookston	1.522	.727	.565	1	.477	.371	.777	380.8
	Grand Rapids	1.615	.818	.604	1	.507	.374	.738	550.0
	University Farm	1.529	.765	.534	1	.500	.349	.698	435.7

[3] Private farm near St. Paul, Minn.

TABLE 3.—*Variation in size of seed of Robust No. 76 beans grown at University Farm when planted at different rates and dates in 1920*

Date of planting	Rate of planting	Length of seed	Width of seed	Thickness of seed	Ratio			Thickness, width factor	Weight per 1,000 seeds
					Length	Width	Thickness		
		Centimeters	*Centimeters*	*Centimeters*					*Grams*
May 5	1 seed each 4 inches	0.935	0.662	0.551	1	0.708	0.589	0.832	217.7
5	1 seed each 8 inches	.949	.673	.559	1	.709	.589	.831	243.8
May 12	1 seed each 3 inches	.945	.677	.562	1	.716	.594	.830	233.0
22	----do	.924	.645	.527	1	.698	.570	.817	211.6
June 22	----do	.901	.651	.597	1	.723	.597	.826	204.4

The growing season of 1919 was favorable throughout at University Farm, but the season of 1920 was less so. Until about July 10 there was heavy precipitation, but during the remainder of the growing season rainfall was scant. The crop of beans produced was affected differently during its development in the two seasons mentioned, as seen in Table 4. Robust beans produced in 1919 weighed 227 g per 1,000, while seeds of the same variety produced in 1920 weighed 177 g per 1,000. The variety Improved Goddard does not show similar variation. Seeds produced by this variety in 1919 weighed 434 g per 1,000, while seeds produced in 1920 weighed 436 g per 1,000. The variety Improved Goddard is an early type, while the variety Robust matures approximately two weeks later when planted at the normal date. At University Farm, Robust beans matured uniformly when planted as late as July 1, while Snowflake beans were nonuniform in maturity. It is probable that Improved Goddard matured before the drought had progressed far enough to hinder normal development, whereas Robust was hampered by the drought. The Robust beans grown on a very sandy soil at Coon Creek in 1920 weighed 157 g per 1,000. These were checked in development by the drought. From the evidence given it appears that seasonal variation may be great enough to make it impossible to base a classification of beans upon size of seed with the expectation that it will be of use over a period of years or in widely different locations.

CHARACTERS USEFUL IN CLASSIFICATION AND DESCRIPTION

The observations here reported are based upon three years' work at University Farm.

SEEDLING CHARACTERS

The term "seedling leaves" as here used refers to the first pair of leaves above the cotyledons. The size of seedling leaves produced is closely correlated with the size of the seed.

TABLE 4.—*Variation in size of two varieties of beans grown at University Farm in 1919 and 1920*

Variety	Year	Length of seed	Width of seed	Thickness of seed	Ratio			Thickness, width factor	Weight per 1,000 seeds
					Length	Width	Thickness		
		Centimeters	*Centimeter*	*Centimeter*					*Grams*
Improved Goddard, No. 139	1919	1.580	0.797	0.539	1	0.504	0.341	0.710	433.8
	1920	1.529	.765	.534	1	.500	.349	.698	435.6
Robust No. 76	1919	.912	.669	.567	1	.733	.622	.847	227.1
	1920	.840	.584	.480	1	.695	.571	.822	176.8

Color of seedling leaves and stem is correlated with color of seed coat. In the brown-seeded varieties the stem is tinted brown, especially close to the surface of the soil. The same color distribution is true of red-seeded varieties. In the solid black or black mottled varieties under observation a purple tint extends into the veins of the seedling leaves. In all except the solid black or black mottled varieties the color soon disappears. However, in the latter group the purple color remains until maturity, especially in the stems. There are varying shades of green, but this occurs in both white-seeded and colored-seeded varieties. The tepary and Lima beans have distinctly dark green seedling leaves. The usefulness of this character is merely supplementary in description.

Freeman (*5*) has pointed out that the length of seedling-leaf petiole is an easy method of distinguishing tepary beans from common beans. The petiole is very short in the former and considerably longer in the latter.

The character of the seedling-leaf surface is useful in identifying a few varieties of the common field beans. The seedling-leaf surface in a majority of the varieties is smooth. However, there are marked gradations of smoothness, ranging from smooth in Navy Pea to very wrinkled in Vineless Marrow. The latter variety is readily distinguished by this character from White Marrow, a long trailing variety having seeds similar in size and appearance.

Pubescence of the seedling leaf surface is useful largely in distinguishing species of the genus Phaseolus. Varieties of the species *acutifolius* and *lunatus* have glabrous leaf surfaces while varieties of *vulgaris* and *multiflorus* have pubescent leaf surfaces.

Seedling characters are of limited value in the identification of varieties.

CHARACTERS OF THE WELL-DEVELOPED PLANTS

Habit of Growth

In habit of growth bean plants may be classified as bush (fig. 1) and trailing (fig. 2). The latter range from short to long trailing, while the former have less range in height due to their habit of growth.

Bush beans are characterized by a determinate growth habit. The plants are erect and have from five to eight nodes in the main axis and terminate in an inflorescence. Emerson (*4*), *p* [*4*] gives the characteristics of bush beans as follows:

> The main axis is terminated by an inflorescence when from about four to eight internodes have developed and can not be forced to make further growth tho provided with the most favorable conditions of moisture and temperature, and even tho the flowers be removed to prevent the drain of seed production.

He believes that the common bush bean is a mutation from the pole bean.

Trailing beans have an indeterminate habit of growth. The plants range from erect (fig. 3) to decumbent (fig. 4) in habit. They may also be grouped as short and long trailing. The short-trailing forms have from 11 to 16 nodes, while the long-trailing forms may have as many as 28 or 30. The first flower clusters appear rather near the base of the stem and the others progressively higher as new nodes are formed. Emerson (*4*) found that if favorable conditions for growth are provided and if heavy seed production is prevented, pole beans can be kept growing for a long time.

Height

Height obviously is determined by number of nodes and internode length. Some trailing varieties have long internodes, others have short ones. For example, White Marrow, in 1920, had an average

FIGURE 1.—Bush habit of Improved Goddard

of 17 nodes with an internode length of 7.8 cm, while Red Indian had the same number of nodes with an average internode length of 4 cm. There appears to be a similar variation in bush varieties. For example, in 1920, Red Kidney had an average of 7 nodes with an internode length of 6.4 cm, while Selection No. 90 had an average of

6 nodes with an internode length of 5.7 cm. Emerson (*4*) reports the existence of distinct types of bush beans with respect to both number and length of internodes. He found this to hold for pole

FIGURE 2.—Trailing habit of the Navy Pea, variety Robust

beans. Data reported in this study were taken when the plants had reached approximately their maximum height. The measurements were taken of representative plants and recorded in centimeters. The number of nodes was determined by averaging the actual count

of 10 representative plants. Both of these determinations were made for the years 1919 and 1920.

Color of Leaves and Stems

The color of fully developed leaves and stems in the majority of the varieties is green throughout. However, in some dark-seeded varie-

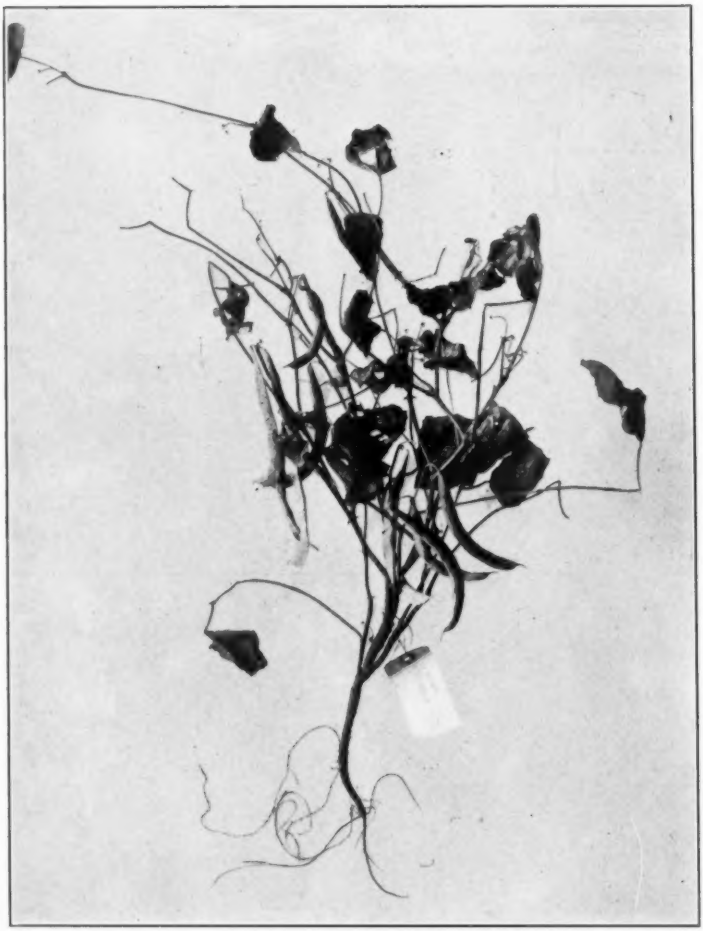

FIGURE 3.—Erect trailing habit of Black Turtle Soup

ties, such as Black Turtle Soup, Zebra, and Selection No. 121, the stems are tinted purple. These same varieties have dark-green leaves. On the other hand, Lady Washington, a white-seeded variety has dark-green leaves. Consequently there appears to be no correla-

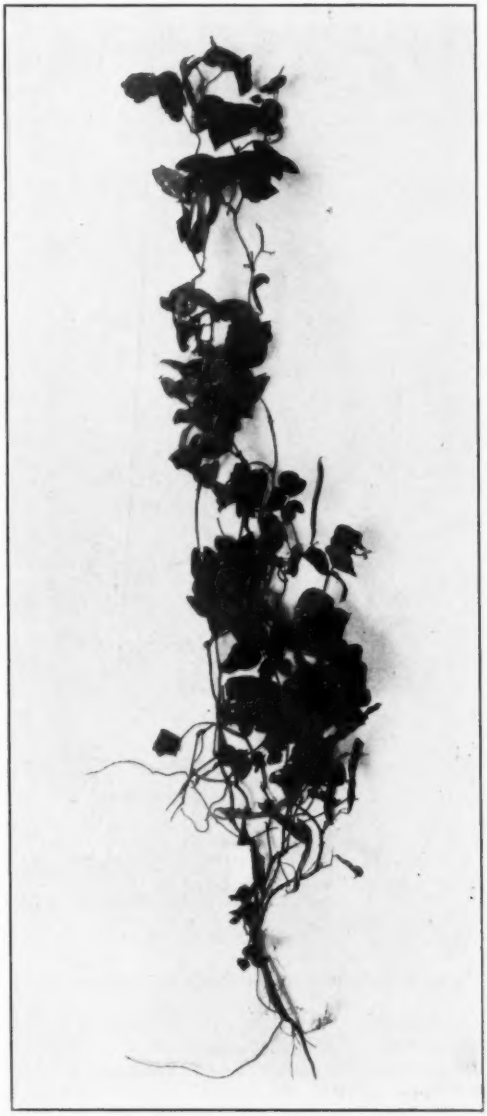

FIGURE 4.—Decumbent habit of Great Northern

tion between the intensity of green color of the leaf and the color of the seed.

Size and Shape of Leaves

The size of the mature leaf varies closely with the size of the seed. On a single plant, leaves vary from small near the growing tip to large where they are fully developed. Previous writers have used size of the leaf in the description of varieties. Irish (*7*) gives the size

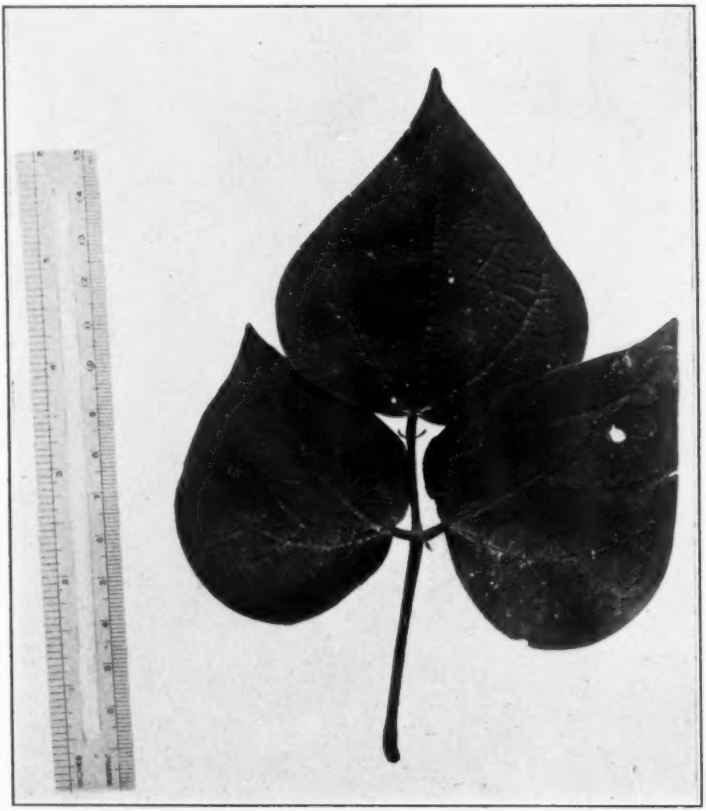

FIGURE 5.—Fully developed leaf of the Navy Pea, variety Robust

in actual measurements while Tracy (*13*) and Jarvis (*8*) use such general terms as large, medium, and small. Freeman (*5*) gives averages of 100 mature leaves taken at random for length and breadth to show that tepary leaves are smaller than common bean leaves. Hendry (*6*) tabulates length and breadth dimensions for the median leaflet of the varieties grown in California. The use of absolute measurements in the description of varieties with a species appears to be impractical because of the wide variation in size of the leaf on a single plant. In these descriptions all determinations of size were

made on fully developed leaves of the variety concerned. The leaf shown in Figure 5 is described as small, that shown in Figure 6 as medium, and that shown in Figure 7 as large.

Mature leaves vary in shape and character of the surface. The leaf shown in Figure 5 is described as small and short pointed, that shown in Figure 6 as medium and long pointed, and that shown in Figure 8

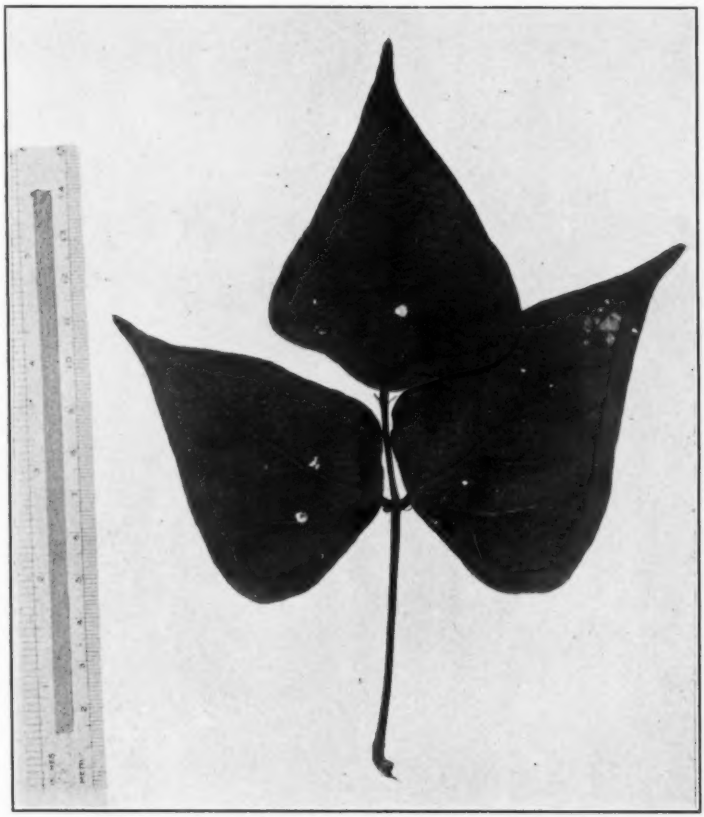

FIGURE 6.—Fully developed leaf of the variety Ruby Horticultural Bush

as broad and short pointed. Mature leaf surfaces are referred to as crumpled (fig. 9) and as smooth (fig. 8).

COLOR OF FLOWERS

Color of blossom was determined by careful comparison of newly opened flowers with the colors of a standard chart (*12*). Since there is a variation in color in the different parts of the corolla, the color was determined for the standard and the wings. Previous writers have recognized color of blossom, but have usually described it in general terms such as "pink" or "violet." Tracy (*13*) refers to the

use of a color chart published by Henri Dauthenay, but does not give specific citation to color plates.

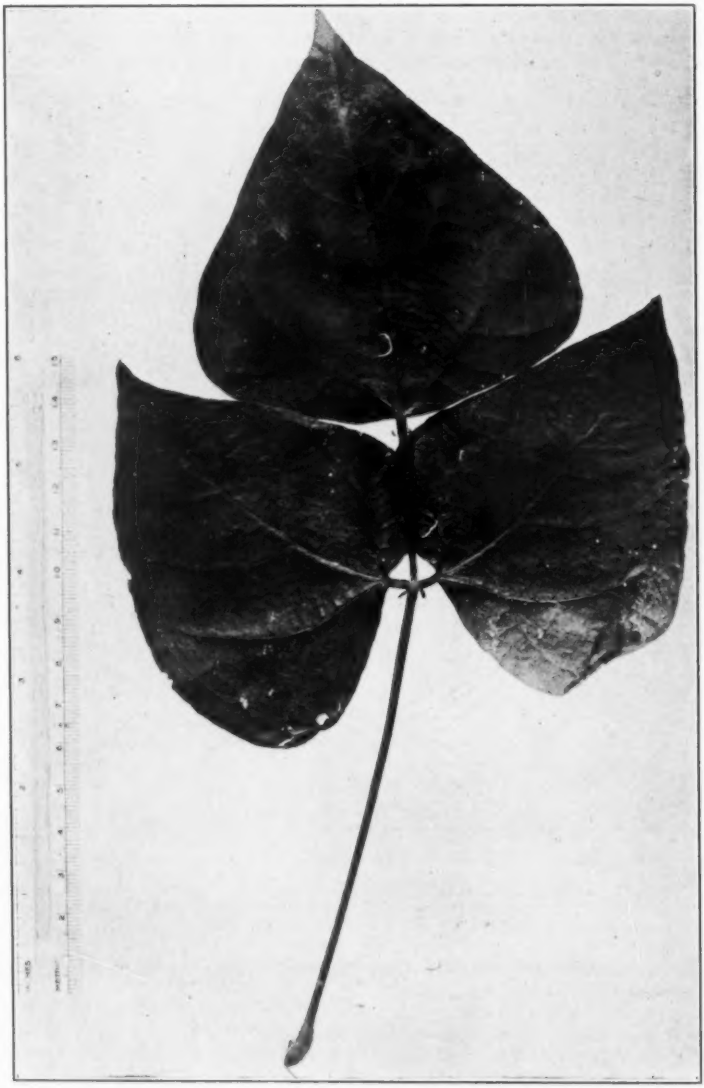

FIGURE 7.—Fully developed leaf of the variety White Marrow

TIME OF MATURITY

Time of maturity is of considerable economic importance, for the length of the growing season limits the growing of some types of

beans which are late in maturing. In identifying varieties otherwise similar in seed and plant characters, the time of maturity is of decided importance. For example, Snowflake and Robust have seed and plant characters which are similar, but the former matures approximately two weeks earlier than the latter when planted at the normal date. Time of maturity as referred to in this study applies to environmental conditions as they are at University Farm.

FIGURE 8.—Fully developed leaf of the variety Arikara Yellow

PRODUCTIVENESS

As a descriptive character productiveness undoubtedly merits consideration. Jarvis (*8*) and Tracy (*13*) use comparative terms to express yields of green snap pods. Hendry (*6*) and Freeman (*5*) give yields in tabular form showing the relative yielding power of the varieties described in their localities. Data on yielding power are of necessity restricted to a given locality. In this discussion four degrees of comparison are used, namely, low, medium, productive, and very productive. In the majority of cases these comparisons are based upon plot tests (8 by 18 feet) repeated four times over a period of three to four years.

Disease Resistance

Disease-resistance data are reported for the crop years 1919, 1920, and 1922. Anthracnose (fig. 10) was the most serious disease prevalent. Leach (*9*) found at least eight distinct biologic forms of this disease. The data are based upon injury to the green pods. It is apparent from the figures shown that there is a wide variation in the susceptibility of varieties to anthracnose. Blight (fig. 11) was less prevalent, and notes were taken on its development only on the

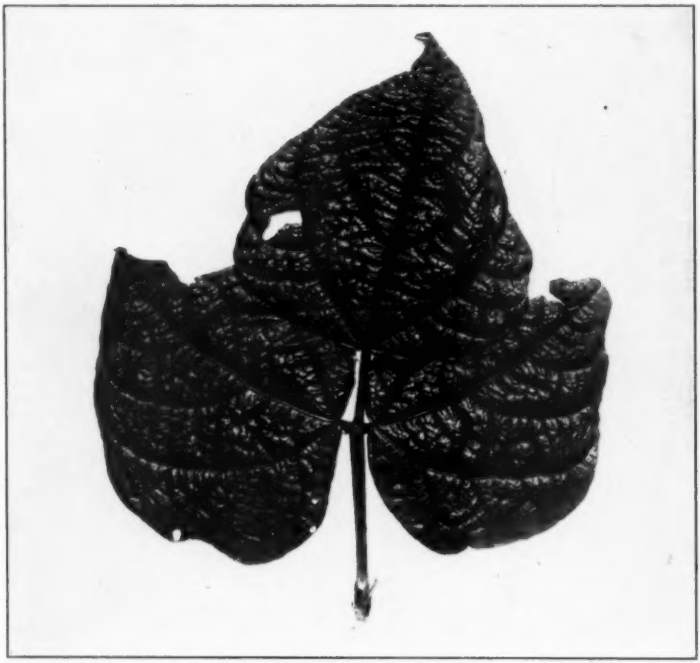

FIGURE 9.—Fully developed leaf of the variety Eureka

green pods. Leaf rust occurred on several of the late-maturing varieties in 1919 and 1921. (Fig. 12.) Under the rather humid condition which prevailed throughout the growing season of 1919 anthracnose did considerable damage, but the rather dry growing season of 1920 apparently checked its development.

POD CHARACTERS

Characters of the pods are not influenced so much as the vegetative parts by the environment and therefore are more useful in distinguishing varieties.

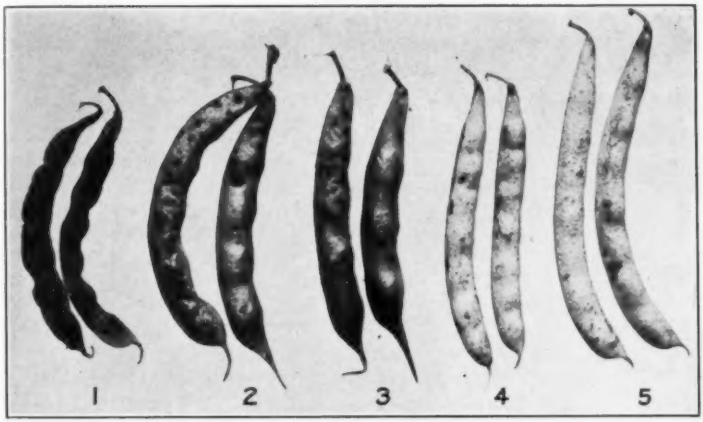

FIGURE 10.—Anthracnose on dry pods of Hidatsa Red (1), Vineless Marrow (2), Ruby Horticultural Bush (3), Robust (4), and Black Turtle Soup (5)

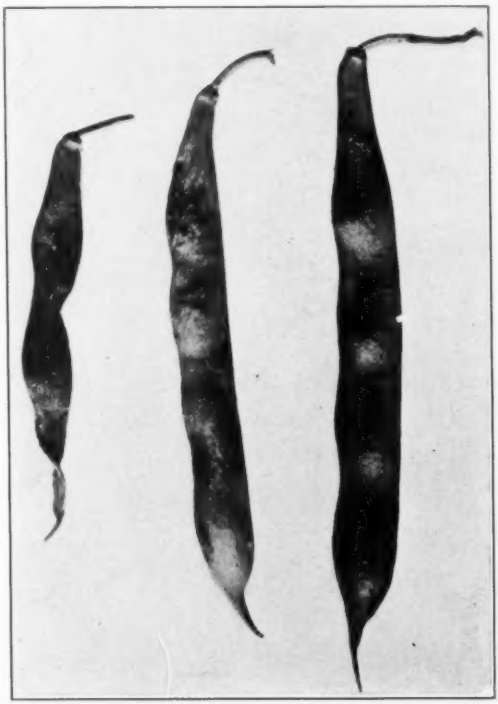

FIGURE 11.—Pods of Red Kidney showing blight injury

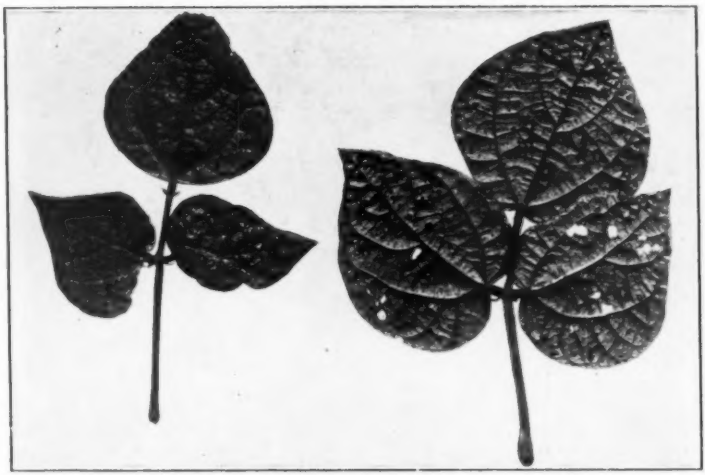

FIGURE 12.—Leaf-rust pustules on upper and lower leaf surfaces of beans

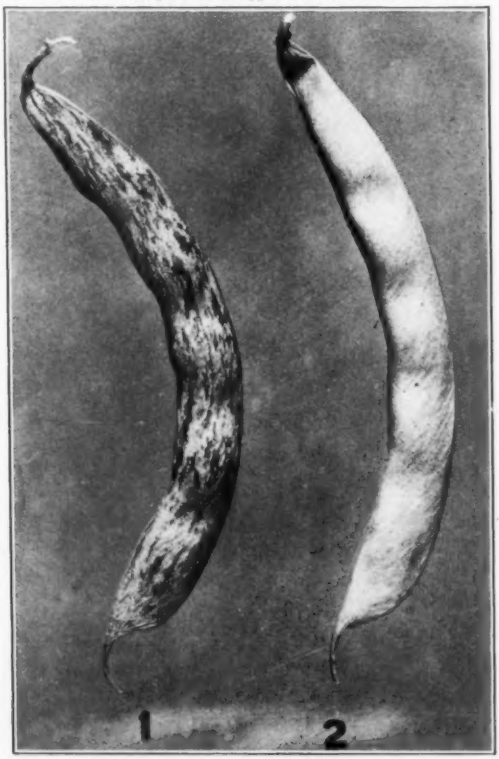

FIGURE 13.—Colored mature pod of Selection No. 148 (1) and colorless mature pod of Arikara Yellow (2)

Color

Many varieties develop a characteristic pod color just as they approach maturity. Selection No. 148, for example, shows very marked purple-splashed areas (fig. 13) which are permanent, while Red Kidney (fig. 14–1), which often has red-tinged areas on the immature pods usually shows no color in the dry mature state. Great Northern, a white-seeded variety, often develops purple-splashed areas which are permanent. Color in pods is described as found at the period approaching maturity. Observations in these cultures indicated no consistent correlation between pod color and other coloration in the plant. This is in accord with the findings of Shaw and Norton (*11*).

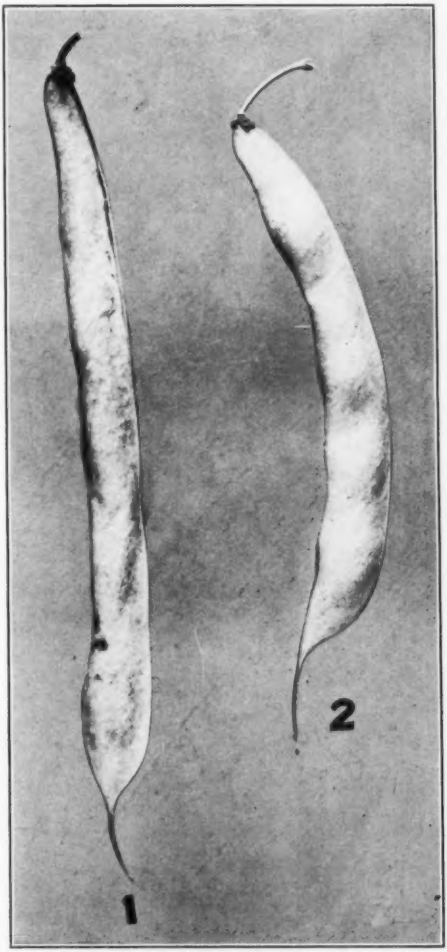

FIGURE 14.—Colorless mature pods of Red Kidney (1) and Selection 90 (2), showing tapering pod apices

Shape

Shape of pods has been used in descriptions by Irish (*7*) and Tracy (*13*). The former introduces into his classification shape of pods as seen in lateral view, while the latter introduces the shape of pod as seen in cross section. Both of these workers considered the pod as found in the immature condition. Since pod characters are rather fixed, both lateral and ventral views are used in this classification. In the lateral view pods are described as long and straight (fig. 15–1), short and straight (fig. 15–3), long and curved (fig. 15–2), short and curved (fig. 15–4), and as curved at the free end and reflexed at the stem end (fig. 15–5). In ventral view the pods are referred to as flat (fig. 16–2) and as rounded (fig. 16–1). Pods which are broad in ventral view are described as rounded.

Texture

Mature pods of field beans vary in texture from coarse, thick, and fibrous to thin, papery, and fibrous. The coarse type is represented by Vineless Marrow (fig. 17–1) and the papery type by Great Northern (fig. 17–2).

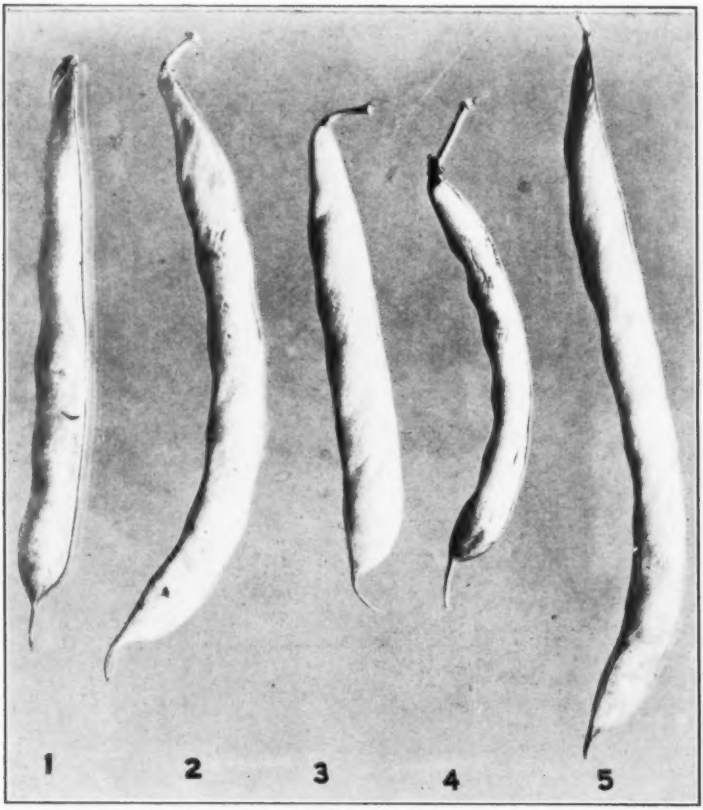

FIGURE 15.—1, Long, straight pod of Red Kidney; 2, long curved pod of Haricot; 3, short straight pod of Selection 109; 4, short curved pod of Brown Swedish 144; 5, pod curved at free end and reflexed at stem end of Selection 162

Length and Width

Length and width of pod have been used in descriptions by previous writers. The general terms "long" and "short" are employed. Tracy (*13*) gives approximate length in inches of snap pods. Hendry (*6*) tabulates pod dimensions in length, breadth, and thickness. In the present descriptions it seemed desirable to present actual measurements for length and width of the dry mature pods made with a caliper to tenths of a centimeter. Length was measured from the tip of the spur to the juncture of the pod and the pedicel.

Width was measured at the widest axis, which was found to be at approximately the second seed from the spur. Pods measuring 0.9 cm or less in width are considered narrow and all over 1.1 cm as wide. Pods with widths in between these arbitrary limits are considered intermediate.

FIGURE 16.—Rounded pod of Vineless Marrow (1) and flat pod of Pearce Improved (2)

APEX

Pod apex as used in these descriptions is that portion of the pod between the base of the spur and the point where the pod begins to taper toward the free end. Apparently previous writers have not distinguished between pod apex and spur. For example, in describing the pod of White Kidney, Tracy (*13*) uses the expression "point of pod medium in length and straight," while Jarvis (*8*) uses the expression "moderately stout straight point." From these quotations it seems that it can be safely inferred that they had reference to the pod spur. Differences in pod apex may readily be seen by examining the apex of Selection No. 90 (fig. 14–2) which tapers off gradually toward the spur, while in Selection 109 the apex tapers off rather abruptly toward the spur (fig. 15–3). The former type of apex is described as elongated and the latter as abrupt.

SPUR

The term "spur" as used in these descriptions refers to the narrow projection at the free end of the pod beginning where the pod ceases to be hollow. This point was determined in order to have a somewhat definite point from which to measure the length of the spur. When the spur extends in line with the ventral suture, it is described as marginal. (Fig. 15–3.) When it extends from a point not in line with the ventral suture, it is described as not marginal. (Fig.

15–1.) Spurs are curved (fig. 15–3) or straight (fig. 15–1). Straight spurs are those which extend approximately in a straight line with the longitudinal axis of the free end of the pod. Curved spurs are those which bend away from a straight line with the longitudinal axis of the free end of the pod toward the dorsal suture.

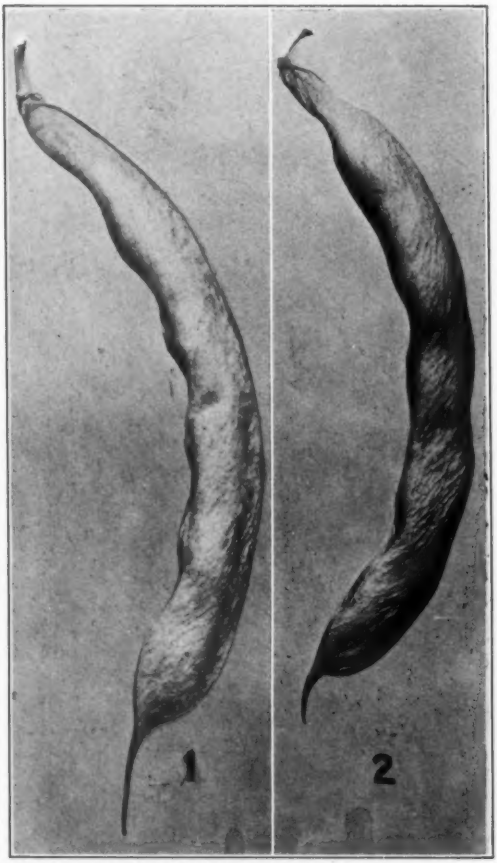

FIGURE 17.—Coarse pod of Vineless Marrow (1) and thin, papery pod of Great Northern (2)

DRY-SEED CHARACTERS

Dry seeds are used exclusively in Jarvis's (*8*) key for the classification of American varieties of beans. All writers have given seeds a prominent place in description, which is in accord with the practice reported in this study.

SIZE

Size of the dry seeds as reported in this discussion is expressed in their three dimensions and number of seeds per 1,000 g. Each measurement was taken with a micrometer at the broadest axis and read to 0.01 mm. The measurements reported in this study are largely based on 100 determinations. In the majority of cases the weighings represent the actual weight of 1,000 seeds. All weighings were made on a No. 17 Troemner balance.

SHAPE

Shape of dry seeds has been recognized by the majority of writers as a characteristic of value in classification. Von Martens (*10*) based his major groups upon shape, while Jarvis (*8*) recognized work done by Gilmore at Cornell in grouping field beans into four market groups, namely, kidney, marrow, medium, and pea. In the present classification seeds are grouped as reniform (fig. 18–1, 2) and not reniform (fig. 18–3 to 6, inclusive). In cross section the seeds are described as flat (fig. 19–1, 2), intermediate (fig. 19–3, 4), and round (fig. 19–5, 6). From the measurements taken a single factor was

derived by dividing the thickness by the width to designate whether the seeds were flat, intermediate, or round. Those with a thickness factor less than seven-tenths are classified as flat, those falling between seven-tenths and eight-tenths are grouped as intermediate, and those with a factor of eight-tenths or over are designated as round. In the descriptions of a few varieties seeds are described as oval (fig. 18–3) and as spherical (fig. 18–4). The ends of seeds are described as round (fig. 18–2, 4) and as truncated (fig. 18–5 and 6).

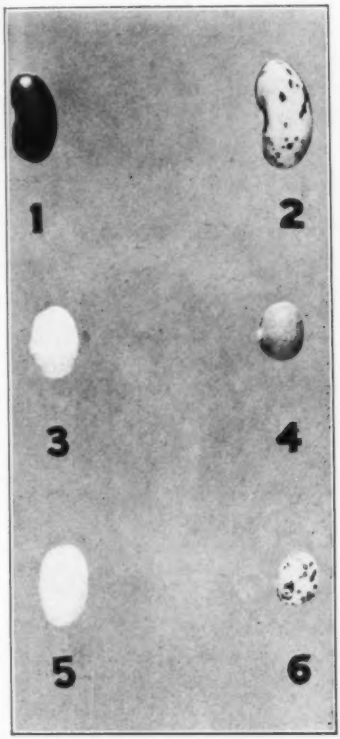

FIGURE 18.—Bean seed of the following varieties: 1, Black Turtle Soup; 2, Improved Goddard; 3, Vineless Marrow; 4, Eureka; 5, Pearce Improved; 6, Wild Goose

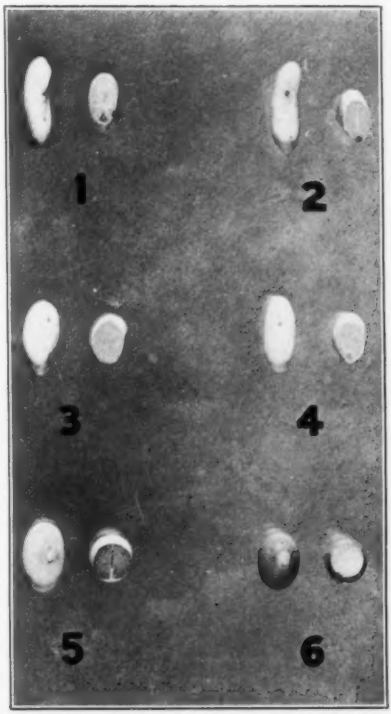

FIGURE 19.—Bean seed and cross sections of the following varieties: 1, Haricot; 2, Great Northern; 3, Burlingame; 4, Selection No. 106; 5, Vineless Marrow; 6, Eureka

COLOR

Color of dry seeds has been used to distinguish varieties by Von Martens and others. Chittenden (*1*) at Wisley places seed color second to pod texture in classifying Dwarf French beans. All writers have recognized color in a general way, but Freeman (*5*) was the first to give specific citations to a standard color chart. In these descriptions beans are arranged in two main groups with respect to color, namely, those with solid-colored seed coats (fig. 20) and those with patterned seed coats (fig. 21). All color types of beans may have

eye markings. The "eye" as referred to in these descriptions is that small colored area surrounding the hilum and above the caruncle, as shown in Figure 22–4. Eyed varieties frequently have a narrow ring immediately surrounding the hilum. This is referred to as the hilum ring. Eyes may be patterned, as in Old Fashioned Yellow Eye (fig. 22–1), in which the eye is defined by an outer snuffbrown ring. At each end of the hilum there is a Roman-ocher colored area, and at each side of the hilum there is a white area which frequently connects up with the white body color of the seed coat. Color patterns are distributed throughout the entire seed coat or are localized in an area of varying size surrounding the eye. Beans with fully patterned seed coats are of three types, namely, those showing longitudinal stripes (fig. 21–1), those showing less definitely defined color areas (fig. 21–4), and those with definitely defined color areas (fig. 21–5). Beans with color patterns surrounding the eye are of two types those showing one color (fig. 22, 1 and 2) and those showing two colors.

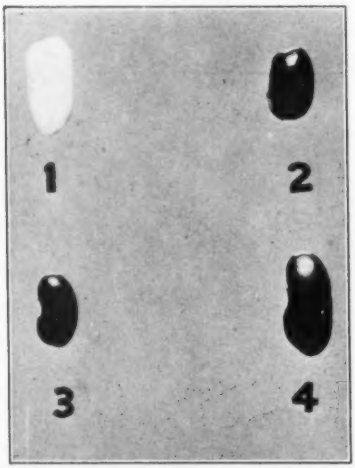

FIGURE 20.—Solid-colored seed coats of beans of the following varieties: 1, White Kidney; 2, Brown Swedish; 3, Black Turtle Soup; 4, Red Kidney

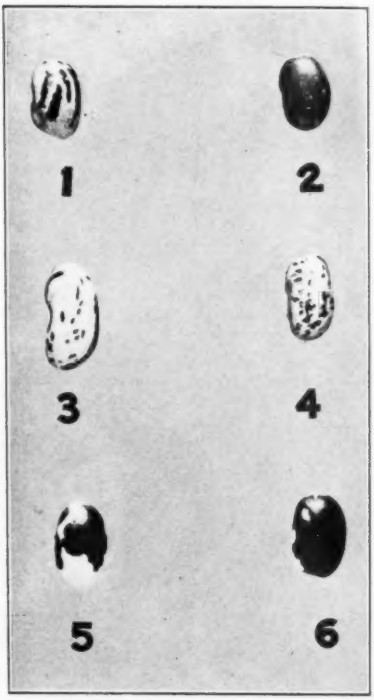

FIGURE 21.—Patterned seed coats of beans of the following varieties: 1, Zebra; 2, Hansen; 3, Improved Goddard; 4, Selection 148; 5-6, Mottled Red Indian

The margins of the patterns surrounding the eye vary in extent and in definiteness. (Fig. 22.) All color determinations as herein reported were made by comparing fresh, fully mature, dry seed with the colors of a standard chart (*12*). In a study of garden beans Shaw and Norton (*11*) point out that there is no consistent correlation between color of seed coat and color of flowers, which is in accord with the findings of this study of field beans.

SUMMARY OF CHARACTERS USEFUL IN CLASSIFYING FIELD BEANS

1. The glabrous leaf character serves to distinguish *Phaseolus lunatus* and *P. acutifolius* A. Gray var. *latifolius* G. F. Freeman from *P. multiflorus* Willd. and *P. vulgaris* L.
2. Radiating lines from the hilum and shape and size of seed permit differentiation between *P. lunatus* and *P. acutifolius* var. *latifolius*.
3. Tuberous roots characterize *P. multiflorus* and a taproot with branches charterizes *P. vulgaris*.
4. The seedlings of *P. multiflorus* do not carry the cotyledons aboveground, whereas the seedlings of *vulgaris* do.
5. The following characters may be used in classifying varieties of the common field bean:
   - *a*. Habit of growth of the plants, bush or trailing.
   - *b*. Number and length of internodes.
   - *c*. Character of leaf surface.
   - *d*. Color of flowers.
   - *e*. Time of maturity.
   - *f*. Pod shape, texture, and color.
   - *g*. Pod dimensions, width and length.
   - *h*. Position, length, and shape of spur.
   - *i*. Dry-seed characters — shape, size, color of seed coat, presence or absence of eye markings, and color of eye.
6. The following vegetative characters may be used in describing varieties:
   - *a*. Size, shape, color, and character of surface of seedling leaves.
   - *b*. Color of mature leaves and stems.
   - *c*. Size and shape of mature leaves.

FIGURE 22.—Eyes of beans of the following varieties: 1, Patterned eye of Old Fashioned Yellow Eye; 2, Improved Yellow Eye; 3, mottled eye pattern of China Red Eye; 4, Long Yellow

CLASSIFICATION AND DESCRIPTION OF FOUR OF THE ECONOMIC SPECIES OF THE GENUS PHASEOLUS

The varieties of beans grown in the United States for human food either in the form of immature pods containing the partially developed seeds, for shell beans or for the dry seed, are very largely included in four species of the genus Phaseolus. The four species may be classified as follows:

A. Leaves glabrous.
   B. Seeds with conspicuous lines radiating from the hilum to the dorsal region; perennial in Tropics. *Phaseolus lunatus* L. Lima bean.
   BB. Seeds without conspicuous lines radiating from the hilum to the dorsal region. *Phaseolus acutifolius* A. Gray var. *latifolius* G. F. Freeman. Tepary bean.

AA. Leaves pubescent.
   B. Roots tuberous, often perennial in warm climates, cotyledons not raised above the ground in the seedlings. *Phaseolus multiflorus*. Runner bean.
   BB. Roots not tuberous, annuals, cotyledons raised above the ground in the seedlings. *Phaseolus vulgaris* L. Common bean.

The following descriptions are largely from the Standard Cyclopedia of Horticulture by Bailey (*2*).

THE LIMA BEAN

The Lima bean is of two main types, in both of which occur dwarf or bush forms. Sieva type has slender stems, thin, short, broad, ovate, pointed leaflets except in the willow leaf forms. Flowers greenish white. Pods small, papery, curved apex ending in distinct spur, seeds small, flat. Relatively early. The Lima type is tall, robust growing, late maturing. Leaflets large and thick. Pods straight without distinct spur, seeds large, flat, or round. Commercial production of the large-seeded type of the Lima bean for the dry seeds is limited in the United States to the southern coast region of California. More Lima beans are produced in California than all the other species combined.

THE TEPARY BEAN

Plants twining, leaflets thin, glabrous, ovate to broadly lanceolate, acuminate. Flowers on peduncles shorter than the leaves, white or pale violet, dry pods papery, flat, straight to slightly curved, with prominent spur. Seeds small, round, oval to nearly round to strongly flattened. A drought-resistant bean adapted to the hot semiarid regions of the Southwest desert region. Forms a small part of the dry beans of commerce.

THE SCARLET RUNNER BEAN

Plants tall, twining, slender, minutely pubescent. Leaflets thin, large, rhombic-ovate, and acute. Flowers on long racemes, pods long with distinct apex, seeds large, much flattened to nearly cylindrical. The Scarlet Runner, with red flowers and colored seeds, and the Dutch Case Knife, with white flowers and seeds, are the two most widely grown varieties of this species.

THE COMMON BEAN

Plants both bush and trailing forms. Leaves and stems pubescent. Leaflets pubescent, rhombic-ovate or ovate in shape, peduncles shorter than the petioles, few flowered. Flowers white, yellowish, or greenish white or lilac. Pods straight or distinctly curved, ending in a distinct spur. Immature pods of snap beans either yellow or green in color, those of field varieties green.

The field varieties of the common bean are distinguished by their fibrous pods from the snap beans, which have very little or no fiber in the pods.

KEY TO THE VARIETIES OF PHASEOLUS VULGARIS

A. Seeds white.
  B. Plants bush.
    C. Seeds reniform to subreniform.
      D. Seeds flat, thickness less than 0.7 of width. p. 29 ..... French Dwarf Kidney
      DD. Seeds round, thickness at least 0.8 of width. p. 29 ..... White Kidney
    CC. Seeds not reniform or subreniform.
      D. Seeds round, thickness at least 0.8 of width, small, conspicuously veined. p. 29 ..... Selection 90.
  BB. Plants trailing.
    C. Seeds reniform to subreniform.
      D. Seeds flat, thickness less than 0.7 of width.
        E. Pods wide, over 1.1 cm.
          F. Pods with uniform curve. p. 29 ..... Haricot.
          FF. Pods curved at free and reflexed at stem end. p. 29 ..... Selection No. 162.
        EE. Pods intermediate in width, 1.1 cm or less.
          F. Pods distinctly curved.
            G. Average width pod 1 cm. p. 30 ..... Great Northern
            GG. Average width pod 1.1 cm. p. 32 ..... Selection 97.
          FF. Pods slightly curved. p. 32 ..... Selection 85.
      DD. Seeds intermediate, thickness 0.7 to 0.8 of width.
        E. Pods flat to intermediate, curved.
          F. Average pod width less than 1 cm. p. 32 ..... Lady Washington.
          FF. Average pod width 1 cm or over. p. 32 ..... Selection 106.

EE. Pods round, curved.
F. Seeds not truncated, medium in size. p. 32---Pilot.
FF. Seeds truncated, small. p. 32---Yankee Winter.
DDD. Seeds round, thickness at least 0.8 width. p. 40---California Wonder.
CC. Seeds not reniform or subreniform.
D. Seeds flat, thickness less than 0.7 of width.
E. Pods broad. p. 40---Pearce Improved.
DD. Seeds intermediate, thickness 0.7 to 0.8 width.
F. Pods straight, broad.
F. Average thickness of seed over 0.7 of width.
G. Average thickness 0.73 of width. p. 40---Burlingame.
GG. Average thickness 0.764 of width. p. 40---Selection 154.
FF. Average thickness of seed 0.7 of width or less.
G. Average length seeds over 0.9 cm. p. 40---White Wonder.
GG. Average length seeds 0.9 cm or less. p. 40---Selection 81.
EE. Pods curved, broad.
F. Pods sharply curved, very broad. p. 40---French White.
FF. Pods slightly curved.
G. Nodes 18–24. p. 41---White Marrow.
GG. Nodes 13–15. p. 41---Selection 100.
DDD. Seeds round, thickness at least 0.8 of width.
E. Seeds large. p. 41---Vineless Marrow.
EE. Seeds small.
F. Pods curved, narrow.
G. Early maturing.
H. Seeds not truncate. p. 41---Snowflake.
HH. Seeds truncate. p. 41---Selection 152.
GG. Medium maturing.
H. Seeds not distinctly truncate. p. 41---Navy Pea.
HH. Seed truncate. p. 41---Robust.
GGG. Late maturing.
H. Spur short, less than 0.6 cm. p. 42---Selection 111.
HH. Spur medium length, between 0.6 and 0.9 cm. p. 42---Selection 112.
FF. Pods straight or reflexed, midlong, frequently tinted purple. p. 42---Blue Pod.
AA. Seeds colored.
B. Plants determinate in growth, bush form.
C. Seeds reniform to subreniform.
D. Seeds intermediate in thickness 0.7 to 0.8 of width.
E. Seeds one color.
F. Seeds garnet brown.
G. Seeds intermediate. p. 42---Red Kidney.
GG. Seeds flat. p. 42---Selection 123.
FF. Seeds plum violet. p. 42---Selection 149.
FFF. Seeds chamois. p. 42---Long Yellow.
EE. Seeds more than one color.
F. Seeds flesh color, mottled garnet brown. p. 43---Improved Goddard.
DD. Seeds round, thickness greater than 0.8 of width.
E. Seeds more than one color.
F. Seeds tan, mottled, madder brown. p. 43---Emperor of Russia.

EE. Seeds one color.
F. Seeds Roman ocher.
G. Mature pods curved.
H. Pods long.
I. Seeds eyed.
J. Stippled. p. 43---Brown Norwegian.
JJ. Not stippled. p. 43---Selection 140.
II. Seeds without eye. p. 43---Selection 150.
HH. Mature pods short, distinctly curved. p. 43---Selection 141.
GG. Mature pods straight. p. 43---Selection 161.
FF. Seeds Naples Yellow. p. 43---Selection 156.
CC. Seeds not reniform or subreniform.
D. Seeds round, thickness of at least 0.8 of width.
E. Seeds solid color.
F. Seeds Naples Yellow. p. 44---Eureka.
FF. Seeds Roman ocher.
G. Seeds eyed.
H. Seed coat not stippled. p. 44---Brown Swedish.
HH. Seed coat stippled. p. 44---Selection 135.
GG. Seeds not eyed. p. 44---Selection 145.
EE. Seeds more than one color.
F. Seeds with irregular ox-blood red pattern at hilum. p. 44---China Red Eye.
FF. Seeds with small irregular yellow ocher pattern at eye. p. 44---Old Fashioned Yellow Eye.
BB. Plants indeterminate in growth, trailing.
C. Seeds reniform to subreniform.
D. Seeds flat, thickness less than 0.7 width.
E. Seeds one color.
F. Seeds raw sienna. p. 45---Arikara Yellow.
FF. Seeds black. p. 45---Black Turtle Soup.
FFF. Seeds plum violet in color.
G. Spur medium length, between 0.6 and 0.9 cm p. 45---Hidatsa Red.
GG. Spur long, over 0.9 cm. p. 45---Selection 128.
FFFF. Seeds snuff brown. p. 45---Selection 147.
EE. Seeds more than one color.
F. Seeds dull purple lake, stippled. p. 45---Selection 142.
FF. Seeds with longitudinal color bands.
G. Seeds smoke gray with black bands. p. 46---Zebra.
GG. Seeds stone colored with vinous mauve bands. p. 46---Hansen.
FFF. Seeds with irregular color pattern.
G. Seeds pale yellow flesh, marked with black. p. 46---Selection 148.
GG. Seeds salmon flesh, marked with snuff brown. p. 46---Garaypata.
GGG. Seeds plum violet and white. p. 46---Mottled Red Indian.
DD. Seeds intermediate in thickness, 0.7 to 0.8 of width.
E. Seeds one color.
F. Seeds raw sienna, small in size. p. 47---Bayou Chico.
FF. Seeds pale pink in color, large in size. p. 47---Bayou Grande.
FFF. Seeds pink in color. p. 47---Pink.
EE. Seeds more than one color.
F. Seeds flesh color, mottled sepia. p. 47---Wild Goose.
CC. Seeds not reniform or subreniform.
D. Seeds round, thickness over 0.8 of width.
E. Seeds more than one color.
F. Seeds with large sharply defined yellow ocher eye pattern. p. 47---Improved Yellow Eye.
FF. Seeds flesh color mottled garnet brown. p. 47---Ruby Horticultural Bush.

DESCRIPTIONS OF VARIETIES OF FIELD BEANS

Seed from the various sources was first grown under the name attached. The names were retained with the types that were true to known variety description. Others were given correct names as they were identified, or, if they were not identified, they are reported here by selection number only. Types selected from certain seed stocks, some of which are probably due to hybridization and therefore not true to any known variety description, are also listed under selection number. Many unidentified types were grown in culture. Since their performance record did not warrant continuation they were discarded. Numbers are carried with the retained varieties for reference.

VARIETIES WITH WHITE SEEDS

All varieties with white seeds have leaves and stems green throughout. Differences in shade of green are mentioned in the descriptions when they are distinct. All the white-seeded varieties used have white flowers.

French Dwarf Kidney, No. 115

Plants strictly bush, height 35 cm, nodes 5–6. Leaves large. Mature pods not colored, slightly curved, medium texture, flat. Pod length 10.33 and width 1.16 cm. Seeds per pod 4.9. Spur not marginal, curved, length 1.02 cm. Dry seeds reniform: length 1.299, width 0.70, and thickness 0.476 cm. Thickness 0.678 of width. Seeds flat; 3,664 seeds per 1,000 g. Color, milk white (*12, p. 11–1, 2*). (Figs. 23–7; 26–4.) Late, low productivity, resistant to anthracnose. From Vilmorin & Co., Paris, France.

White Kidney, No. 104

Plants strictly bush, height 45–50 cm, nodes 5–6. Leaves large, broad, long pointed. Mature pods not colored, straight, round, length 12.966 cm, width 0.978 cm. Seeds per pod 4.1. Apex abrupt. Spur not marginal, straight, length 1.464 cm. Dry seeds reniform; length 1.597, width 0.729, thickness 0.555 cm. Thickness 0.760 of width; seeds intermediate; 2,067 seeds per 1,000 g. Color, milk white (*12, p. 11–1, 2*). (Figs. 23–8; 26–5.) Late, low productivity, resistant to anthracnose. From Minnesota Agricultural Experiment Station. St. Paul, Minn., and several seed houses.

Selection 90

Plants strictly bush, height 28–34 cm, nodes 5–6. Leaves medium size, long pointed. Mature pods not colored, distinctly curved, round, length 0.025, width 0.956 cm. Seeds per pod 4.6. Spur, marginal, straight, length 1.244 cm. Dry seeds not reniform, conspicuously veined, length 0.873, width 0.651, thickness 0.563 cm. Thickness 0.864 of width. Seeds spherical; 4,473 seeds per 1,000 g. Color fleshy white (*12 p. 9*). (Figs. 23–9; 26–6). Early, low productivity and quality, resistant to anthracnose. From Canada.

Haricot, No. 103

Plant long trailing, height 75 to 140 cm, nodes 14–18. Leaves large, broad, short pointed. Seedling leaves rough wrinkled. Mature pods not colored, medium texture, curved, flat, length 12.215, width 1.241 cm. Seeds per pod 4.2. Apex elongate. Spur marginal, curved, length 1.348 cm. Dry seeds reniform; length 1.423, width 0.818, thickness 0.480 cm. Thickness 0.587 of width. Seeds flat; 2,597 seeds per 1,000 g. Color milk white (*12, p, 11–1, 2*). (Figs. 23–10; 26–7.) Very late, medium productivity, resistant to anthracnose.

Selection 162

Similar to Haricot; nodes 17–22. Mature pods not colored, curved at free end and reflexed at stem end, medium texture, length 12.53, width 1.397 cm. Apex elongate. Spur marginal, curved, length 1.027 cm. Dry seeds reniform;

length 1.325, width 0.762, thickness 0.483 cm. Thickness 0.633 of width. Seeds flat; 2,584 seeds per 1,000 g. (Figs. 23–11; 26–8.) Very late, low productivity, resistant to anthracnose.

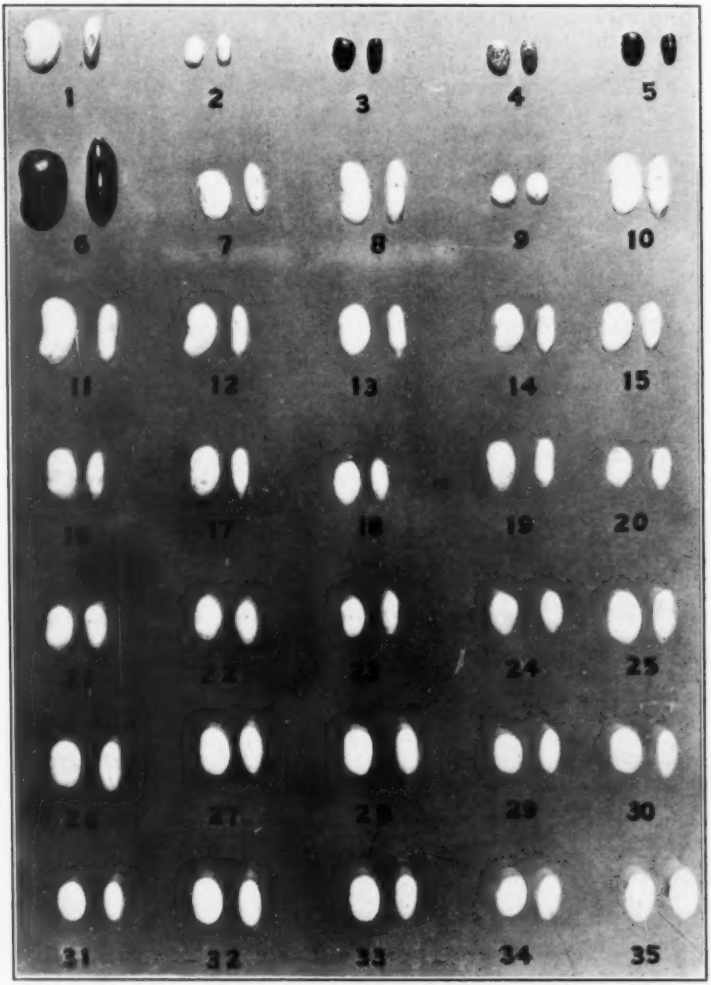

FIGURE 23.—Side and ventral views of ripe seeds: 1, Dwarf Lima; 2, White Tepary; 3, Yellow Tepary; 4, Mottled Tepary; 5, Black Tepary; 6, Scarlet Runner; 7, French Dwarf Kidney, No. 115; 8, White Kidney, No. 104; 9, Selection 90; 10, Haricot, No. 103; 11, Selection 162; 12, Great Northern, No. 78; 13, Selection 97; 14, Selection 86; 15, Selection 163; 16, Selection 85; 17, Selection 166; 18, Lady Washington, No. 82; 19, Selection 106; 20, Selection 89; 21, Selection 164; 22, Pilot, No. 83; 23, Yankee Winter, No. 107; 24, California Wonder, No. 91; 25, Pearce Improved, No. 70; 26, Burlingame, No. 80; 27, Selection 109; 28, Selection 154; 29, Schofield Pea, No. 88; 30, White Wonder, No. 92; 31, Selection 81; 32, French White, No. 98; 33, White Marrow, No. 87; 34, Selection 100; 35, Vineless Marrow, No. 79. × 9/10.

GREAT NORTHERN, NO. 78

Plant short trailing, height 70.75 cm, nodes 16–20. Leaves medium size, short pointed. Mature pods often splashed purple, distinctly curved, flat,

papery in texture, length 9.295, width 1.013 cm. Seeds per pod 4.8. Apex slightly elongated. Spur marginal, curved, length 0.899 cm. Dry seeds reniform; length 1.325, width 0.715, thickness 0.477 cm. Thickness 0.667 of width.

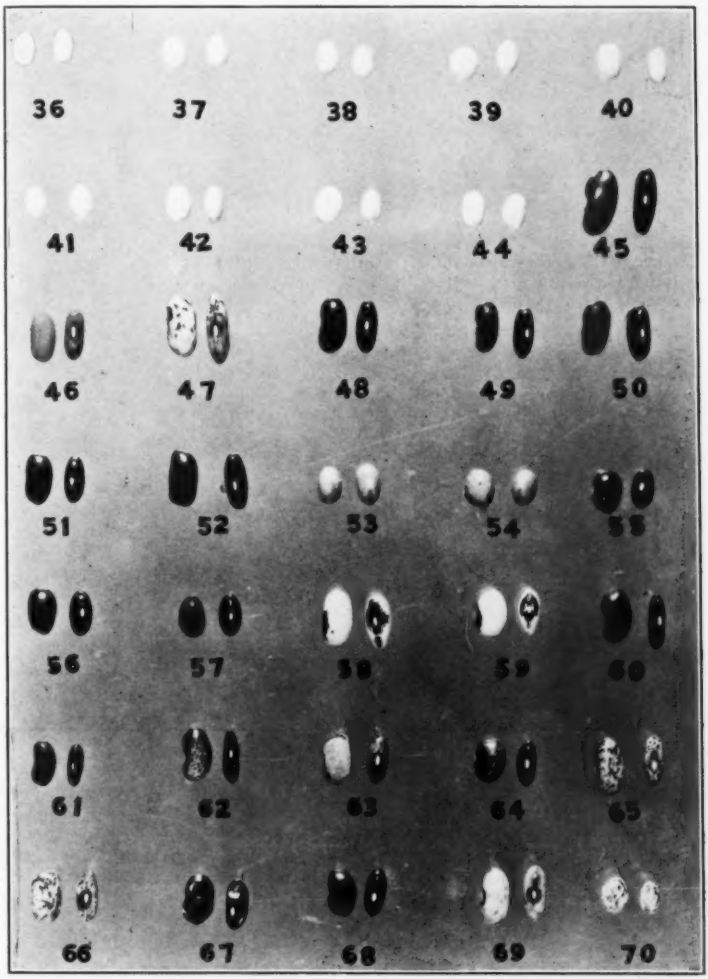

FIGURE 24.—Side and ventral views of ripe seeds: 36, Navy Pea, No. 94; 37, Snowflake, No. 75; 38, Selection 152; 39, Wolverine, No. 110; 40, Robust, No. 76; 41, French Dwarf Rice, No. 101; 42, Selection 112; 43, Selection 111; 44, Blue Pod, No. 102; 45, Red Kidney, No. 116; 46, Long Yellow, No. 124; 47, Improved Goddard, No. 139; 48, Selection 140; 49, Brown Norwegian, No. 133; 50, Selection 150; 51, Selection 141; 52, Selection 161; 53, Selection 156; 54, Eureka, No. 130; 55, Brown Swedish, No. 144; 56, Selection 135; 57, Selection 145; 58, China Red Eye, No. 151; 59, Old Fashioned Yellow Eye, No. 125; 60, Arikara Yellow, No. 117; 61, Black Turtle Soup, No. 118; 62, Selection 142; 63, Zebra, No. 126; 64, Hansen, No. 122; 65, Selection 148; 66, Garaypata, No. 127; 67, Mottled Red Indian, No. 157; 68, Bayou Chico, No. 158; 69, Bayou Grande, No. 159; 70, Wild Goose, No. 121. × 9/10.

Seeds flat; 3,357 seeds per 1,000 g. Color creamy white (*12, p. 10–1, 2*). (Figs. 23–12; 27–1.) Veined. Medium late, productive, susceptible to anthracnose. Synonym South Dakota Improved.

Selection 97

Similar to Great Northern. Pods more curved, length 11.05, width 1.33 cm. Seeds per pod 5.2. Dry seeds, length 1.235, width 0.706, thickness 0.480 cm. Thickness 0.679 of width. Seeds flat. (Figs. 23–13; 27–2.) Received under name of French Dwarf Kidney.

Selection 85

Similar to Great Northern. Pods only slightly curved, length 9.464, width 1.015 cm. Seeds per pod 5.1. Dry seeds less reniform, length 1.203, width 0.713, thickness 0.502 cm. Thickness 0.704 of width. Seeds flat. (Figs. 23–16; 27–3.)

Lady Washington, No. 82

Plant short trailing, height 65–70 cm, nodes 17–20. Leaves dark green, medium size, short pointed. Pods medium texture, not colored, slightly curved, flat, length 9.790, width 0.873 cm. Seeds per pod 5.5. Apex elongated. Spur marginal, curved, length 0.965 cm. Dry seeds subreniform, ends round, length 0.899, width 0.607, thickness 0.430 cm. Thickness 0.708 of width. Seeds flat; 5,544 seeds per 1,000 g. Color milk white (*12, p. 11–1, 2*). (Figs. 23–18; 27–4.) Late,

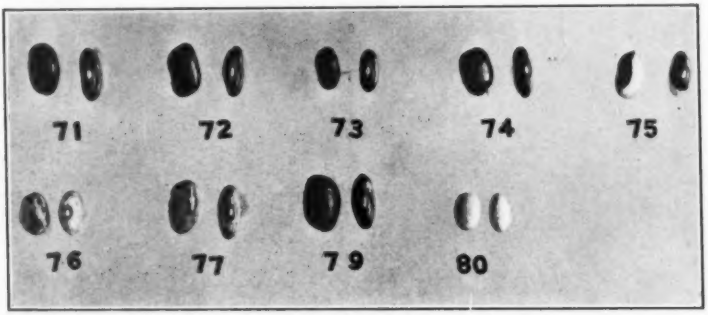

Figure 25.—Side and ventral views of ripe seeds: 71, Hidatsa Red, No. 131; 72, Selection 128; 73, Selection 136; 74, Selection 147; 75, Improved Yellow Eye, No. 120; 76, Ruby Horticultural Bush, No. 129; 77, Selection 143; 79, Pink, No. 160; 80, Small White, No. 106. × 5/6.

medium productivity, resistant to anthracnose. Not well adapted to this section. From Germaine Seed Co., Los Angeles, Calif.

Selection 106

Similar to Lady Washington. Mature pods, length 10,968, width 1.067 cm. Seeds per pod 5.0. Apex abrupt. Spur marginal, curved, length 0.833 cm. Dry seeds, length 1.164, width 0.680, thickness 0.505 cm. Thickness 0.741 of width; 3,494 seeds per 1,000 g. (Figs. 23–19; 27–5.) Productive. Susceptible to anthracnose. Received under the name of Small White.

Pilot, No. 83

Plant short trailing, height 60–65, cm, nodes 16–18. Leaves medium size, short pointed, dark green. Mature pods not colored, curved, length 9.585, width 1.475 cm. Apex abrupt. Spur not marginal, curved, length 1.437 cm. Seeds per pod 5.2. Dry seeds, length 0.824, width 0.617, thickness 0.512 cm. Thickness 0.830 of width. Seeds round; 4,237 seeds per 1,000 g. Color milk white (*12, p. 11–1, 2*). (Fig. 23–22.) Productive, resistant to anthracnose. From Will Seed Co., Bismarck, N. Dak.

Yankee Winter, No. 107

Plant short trailing, height 65–75 cm, nodes 18–22. Leaves small, short pointed. Mature pods not colored, slightly curved, round, medium texture, ventral suture depressed, length 8.948, width 0.762 cm. Apex slightly elongated. Spur marginal,

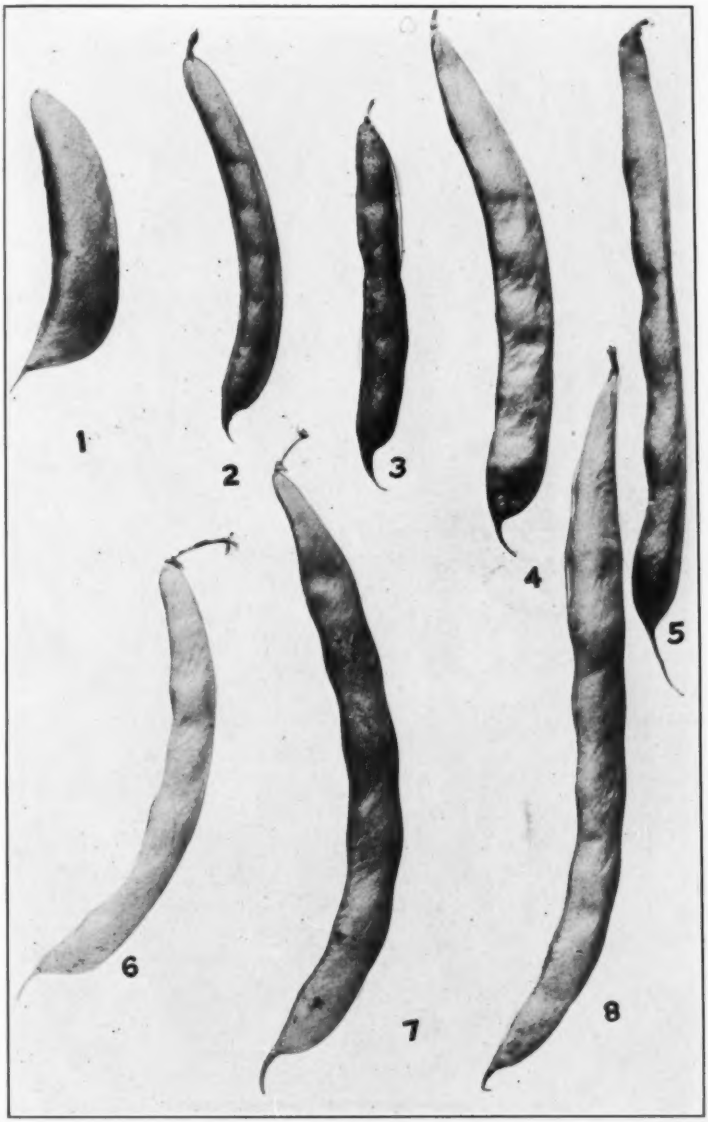

FIGURE 26.—Side view of mature pods: 1, Dwarf Lima; 2, White Tepary; 3, Yellow Tepary; 4, French Dwarf Kidney, No. 115; 5, White Kidney, No. 104; 6, Selection 90; 7, Haricto, No. 103; 8, Selection 162. × 7/10

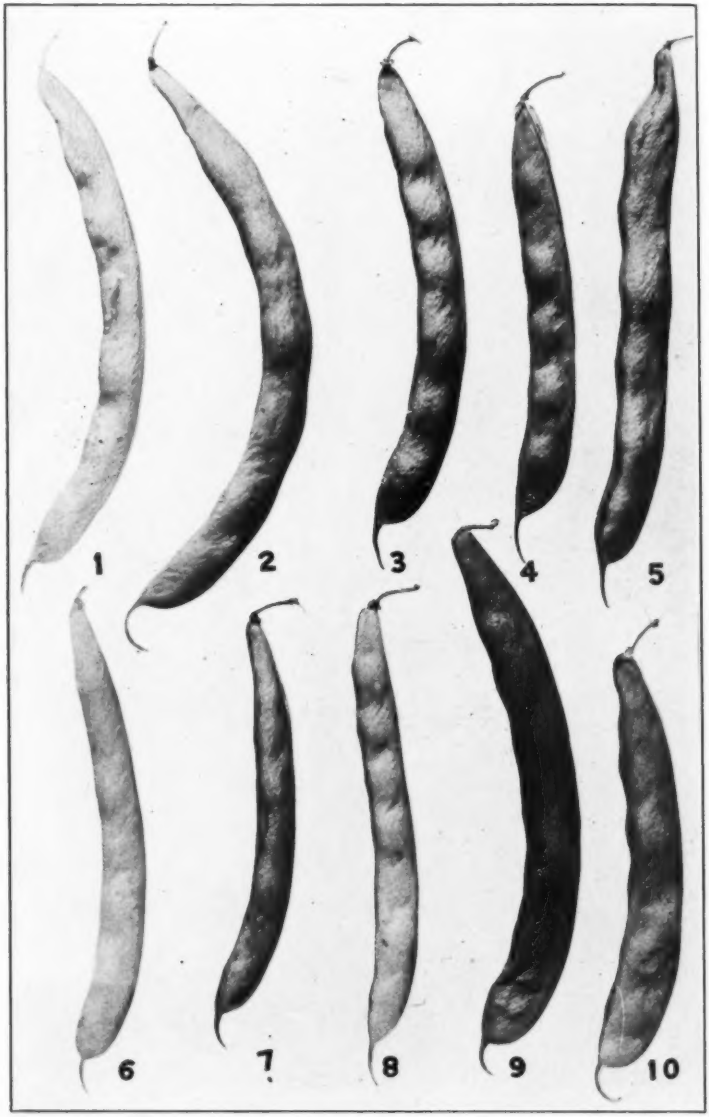

FIGURE 27.—Side view of mature pods: 1, Great Northern, No. 78; 2, Selection 97; 3, Selection 85; 4, Lady Washington, No. 82; 5, Selection 106; 6, Selection 164; 7, Yankee Winter, No. 107; 8, California Wonder, No. 91; 9, Pearce Improved, No. 70; 10, Burlingame, No. 80. × 7/10

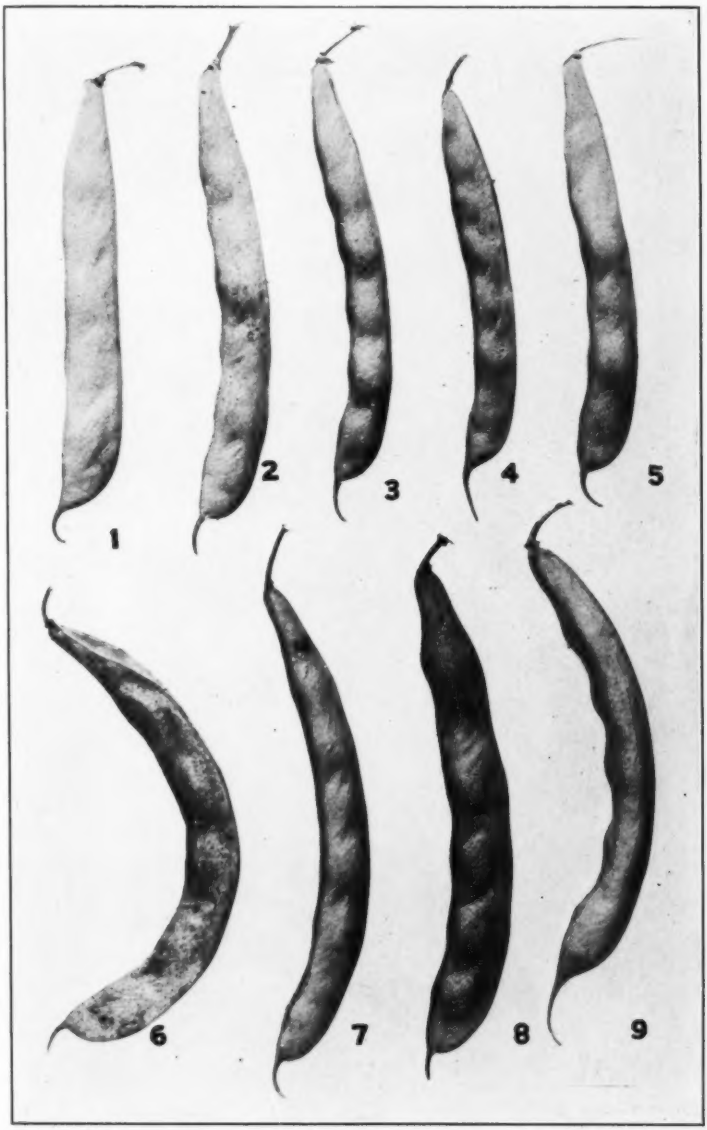

FIGURE 28.—Side view of mature pods: 1, Selection 109; 2, Selection 154; 3, Schofield Pea, No. 88; 4, Selection 81; 5, White Wonder, No. 92; 6, French White, No. 98; 7, White Marrow, No. 87; 8, Selection 100; 9, Vineless Marrow, No. 79. × 1/10

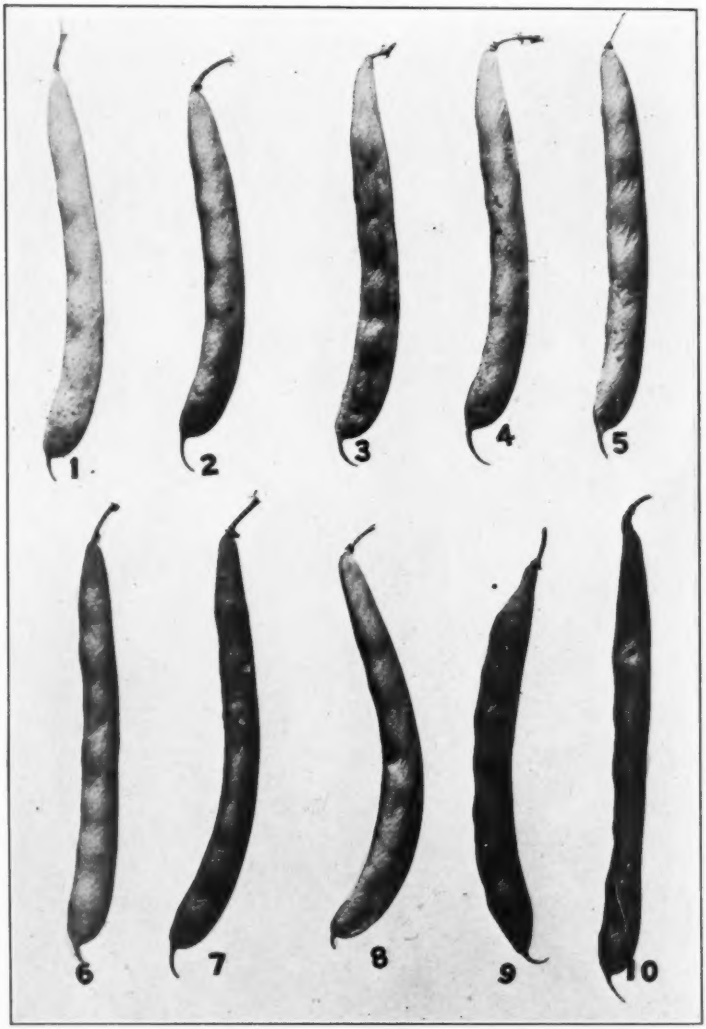

FIGURE 29.—Side view of mature pods: 1, Navy Pea, No. 94; 2, Snowflake, No. 75; 3, Selection 152; 4, Wolverine, No. 110; 5, Robust, No. 76; 6, French Dwarf Rice, No. 101; 7 ,Selection 112; 8, Selection 111; 9 and 10, Blue Pod, No. 102. × 7/10

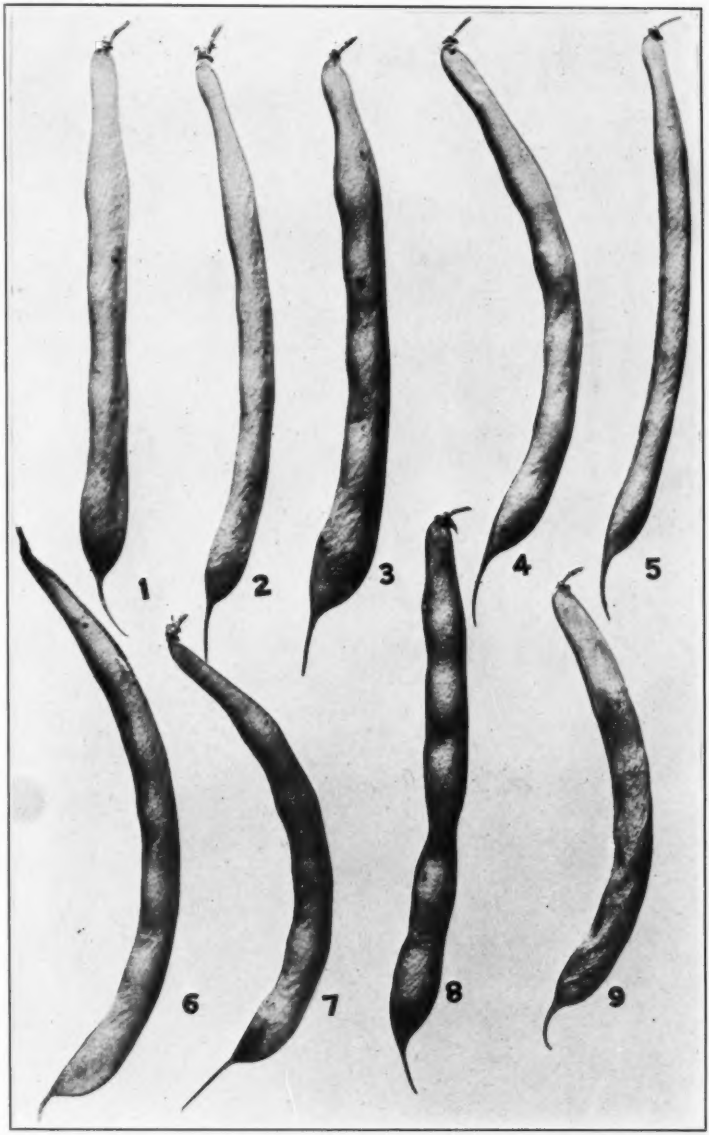

FIGURE 30.—Side view of mature pods: 1, Red Kidney, No. 116; 2, Long Yellow, No. 124; 3, Improved Goddard, No. 139; 4, Selection 140; 5, Brown Norwegian, No. 133; 6, Selection 150; 7, Selection 141; 8, Selection 161; 9, Selection 156. × 7/10

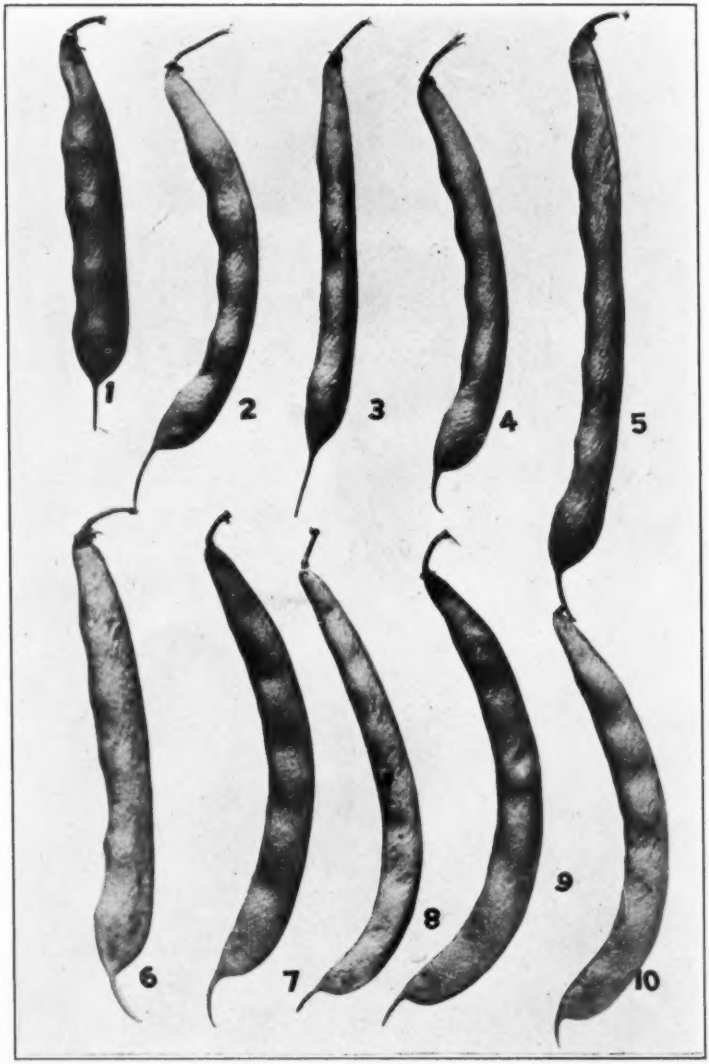

FIGURE 31.—Side view of mature pods: 1, Eureka, No. 130; 2, Brown Swedish, No. 144; 3, Selection 135; 4, Selection 145; 5, China Red Eye, No. 151; 6, Old-Fashioned Yellow Eye, No. 125; 7, Arikara Yellow, 117; 8, Black Turtle Soup, No. 118; 9, Selection 142; 10, Zebra, No. 126. × 7/10

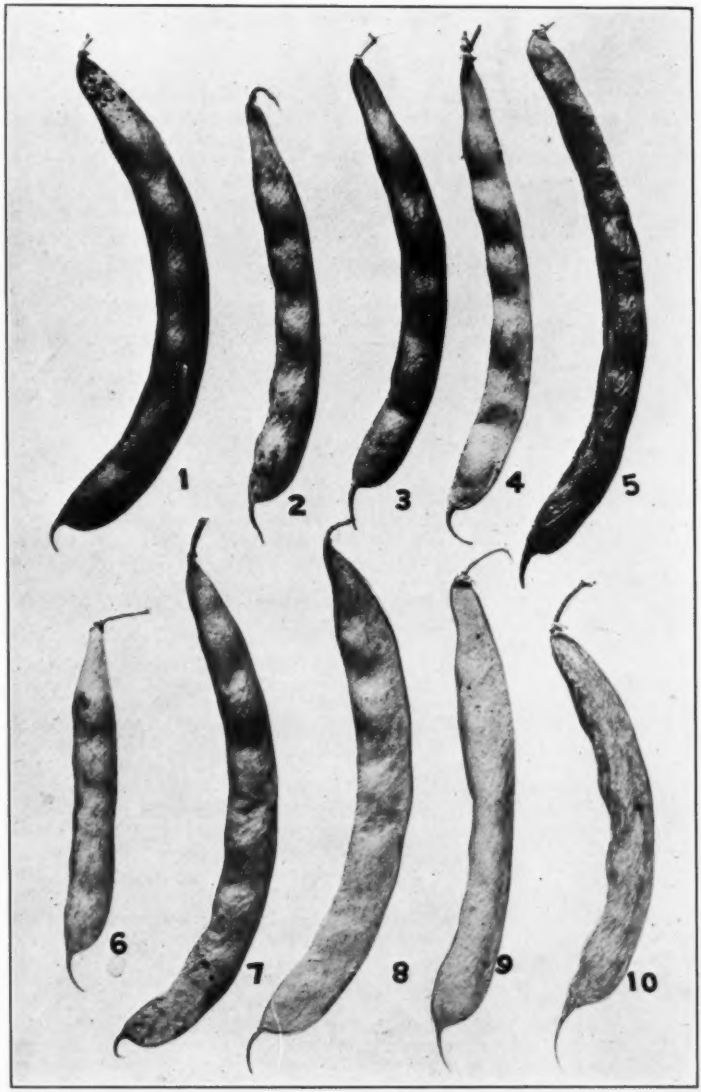

FIGURE 32.—Side view of mature pods: 1, Hansen, No. 122; 2, Selection 148; 3, Garaypata, No. 127; 4, Bayou Chico, No. 158; 5, Bayou Grande, No. 159; 6, Wild Goose, No. 121; 7, Hidatsa Red, No. 131; 8, Selection 147; 9, Improved Yellow Eye, No. 120; 10, Ruby Horticultural Bush, No. 129. × 7/10

curved, length 0.719 cm. Seeds per pod 6.2. Dry seeds reniform, ends truncate, length 0.844, width 0.554, thickness 0.429 cm. Thickness 0.762 of width. Seeds intermediate; 6,644 seeds per 1,000 g. Color milk white (*12, p. 11–1, 2*). (Figs. 23–23; 27–7.) Very late, low productivity, susceptible to anthracnose. From an exhibit at the Minnesota State fair.

California Wonder, No. 91

Plant short trailing, height 90–120 cm, nodes 18–24. Leaves small, short pointed. Mature pods not colored, medium texture, curved, length 9.570, width 0.887 cm. Seeds per pod 5.9. Apex slightly elongated. Spur marginal, curved, length 0.808 cm. Dry seeds subreniform, ends round, length 0.938, width 6.34, thickness 0.513 cm. Thickness 0.808 of width. Seeds round; 4,905 seeds per 1,000 g. Color milk white (*12*, p. *11–3, 4*). (Figs. 23–24; 27–8.) Late, medium productive, susceptible to anthracnose. From Northrup, King & Co., Minneapolis, Minn.

Pearce Improved, No. 70

Plant short trailing, height 80 to 110 cm, nodes 16–22. Leaves medium size, short pointed. Mature pods not colored, thin, very flat, curved, length 10.275, width 1.23 cm. Seeds per pod 4.2. Apex abrupt. Spur curved, marginal, average length 1.098 cm. Dry seeds not reniform, ends truncated, length 1.176, width 0.761, thickness 0.494 cm. Thickness 0.649 of width. Seeds flat; 3,185 seeds per 1,000 g. Color milk white (*12, p. 11–1, 2*). (Figs. 23–25; 27–9.) Very late, productive, susceptible to anthracnose. From Ontario Agricultural College, Guelph, Ontario.

Burlingame, No. 80

Plant short trailing, height 80–90 cm, nodes 15–16. Leaves medium size, short pointed. Mature pods not colored, medium texture, straight, flat, length 10.146, width 1.163 cm. Seeds per pod 4.5. Spur marginal, curved, length 1.151 cm. Dry seeds not reniform, ends truncated, length 1.087, width 0.735, thickness 0.538 cm. Thickness 0.730 of width. Seeds intermediate; 3,044 seeds per 1,000 g. Color milk white (*12, p. 11–1, 2*). (Figs. 23–26; 27–10.) Medium late, productive, susceptible to anthracnose. Synonyms Medium and Schofield Pea. From several seedsmen.

Selection 154

Similar to Burlingame. Mature pods slightly curved, less flattened. Length 9.904, width 1.127 cm. Apex abrupt. Spur marginal, length 1.179. Dry seed, length 1.058, width 0.750, thickness 0.570 cm. Thickness 0.764 of width. Seeds intermediate. (Figs 23–28; 28–2.) From Ontario Agricultural College, Guelph, Ontario, under name of Medium.

White Wonder, No. 92

Similar to Burlingame. Dry pods. Length 0.739, width 1.127 cm. Seeds per pod 3.9. Spur length 1.034 cm. Dry seeds, length 1.042, width 0.702, thickness 0.493 cm. Thickness 0.702 of width. Seeds flat. (Figs. 23–30; 28–5.)

Selection 81

Similar to White Wonder but shorter pod and shorter, flatter seed. Dry seed, length 0.898, width 0.670, thickness 0.457 cm. Thickness 0.680 of width. Seeds flat. (Figs. 23–31; 28–4.)

French White, No. 98

Plant short trailing, height 95 cm, nodes 16–18. Leaves medium size, short pointed. Mature pods not colored, thin, decidedly curved, very flat, length 11.767, width 1.297 cm. Seeds per pod 5.6. Apex abrupt. Spur not marginal, curved, length 1.028 cm. Dry seeds not reniform, ends round, length 1.113, width 0.740, thickness 0.569 cm. Thickness 0.769 of width. Seeds intermediate; 3,190 seeds per 1,000 g. Color milk white (*12, p. 11–1, 2*). (Figs. 23–32; 28–6.) Low productivity. From A. H. Huchting, Oceanside, Calif.

White Marrow, No. 87

Plant long trailing, height 135–145 cm, nodes 18–24. Leaves large, long pointed. Mature pods not colored, medium texture, slightly curved, flat, length 10.719, width 1.079 cm. Seeds per pod 5.8. Spur not marginal, curved, length 0.905 cm. Dry seeds not reniform, ends round, length 1.021, width 0.697, thickness 0.560 cm. Thickness 0.809 of width. Seeds round; 3,827 seeds per 1,000 g. Color milk white (*12, p. 11–1, 2*). (Figs. 23–33; 28–7.) Very late, productive, susceptible to anthracnose. From several seedsmen.

Selection 100

Similar to White Marrow, but lower growing, 90 cm tall, and smaller number of nodes, 13–15. Dry-pod length 10.332, width 1.244 cm. Spur length 0.994 cm. Seeds per pod 5.5. Dry seeds, length 1.013, width 0.719, thickness 0.582 cm. Thickness 0.809 of width. (Figs. 23–34; 28–8.)

Vineless Marrow, No. 79

Plant short trailing, height 80 cm, nodes 12–16. Seedling leaves wrinkled. Leaves large, broad, long pointed. Mature pods not colored, coarse, curved, round, length 10.539, width 1.104 cm. Seeds per pod 4. Apex elongated. Spur not marginal, straight to slightly curved, length 1.431 cm. Dry seeds not reniform, ends round, length 1.129, width 0.762, thickness 0.676 cm. Thickness 0.887 of width. Seeds round and seed coat often wrinkled; 2,180 seeds per 1,000 g. Color milk white (*12, p. 11–3, 4*). (Figs. 23–35; 28–9.) Late, productive, very susceptible to anthracnose. From Ontario Agricultural College, Guelph, Ontario, and from several seedsmen.

Snowflake, No. 75

Plant short trailing, erect, height 75–80 cm, nodes 16–20. Leaves small, short pointed. Mature pods not colored, medium in texture, slightly curved, length 8.497, width 0.886 cm. Spur not marginal, length 0.804 cm. Seeds per pod 5.3. Dry seeds not reniform, ends round, length 0.826, width 0.62, thickness 0.519 cm. Thickness 0.837 of width. Seeds round. Color milk white (*12, p. 11–1, 2*). (Figs. 24–37; 29–2.) Early maturing, productive. From Gregory & Sons, Boston, Mass., and from several other sources. Wolverine is similar with slightly more globose seeds. (Figs. 24–39; 29–4.)

Selection 152

Similar to Snowflake. Pods round, length 8.805, width 0.785 cm. Seeds per pod 5.7. Spur length 0.846 cm. Dry seeds truncated, length 0.818, width 0.556, thickness 0.471 cm. Thickness 0.832 of width. Seed coat fleshy white (*12, p. 9*), veined. (Figs. 24–38; 29–3.) Early maturing, moderately productive. From a farm in Washington County, Minn., on which it had been grown for a number of years.

Navy Pea, No. 94

Plant short trailing, much branched, erect, height 75–80 cm, nodes 16–20. Leaves small, short pointed. Mature pods not colored, medium texture, slightly curved, length 8.644, width 0.882 cm. Seeds per pod 4.9. Apex abrupt. Spur not marginal, curved, length 0.819 cm. Dry seeds not reniform, slightly truncated, length 0.813, width 0.605, thickness 0.523 cm. Thickness 0.864 of width. Seeds round; 4.905 seeds per 1,000 g. Color milk white (*12, p. 11–1, 2*). (Fig. 24–36· 29–1.) Medium early maturing, productive, resistant to anthracnose and blight From Northrup, King & Co. of Minneapolis, Minn. French Dwarf Rice, No. 101 is similar to Navy Pea. (Figs. 24–41; 29–6.)

Robust, No. 76

Similar to Navy Pea. Seeds more truncated and conspicuously veined. Pod measurements, length 8.895, width 0.886 cm. Spur length 0.810 cm. Seeds per pod 5.7. Dry seeds, length 0.844, width 0.600, thickness 0.499 cm. Thickness 0.832 of width. Seeds round. Color fleshy white (*12, p. 9*). Medium early maturing, very productive, resistant to anthracnose and blight. Mosaic not observed on plants. (Figs. 24–40; 29–5.)

Selection 111

Similar to Navy Pea but distinct in having shorter spur. Spur length 0.507 cm. Pod measurements, length 8.335, width 0.90 cm. Seeds per pod 4.9. Dry seeds, length 0.848, width 0.633, thickness 0.526 cm. Thickness 0.831 of width. Seeds round. Late maturity. Medium productivity. (Figs. 24–43; 29–8.)

Selection 112

Similar to Navy Pea but later in maturity. Pod measurements, length 8.49, width 0.820 cm. Spur length 0.786 cm. Seeds per pod 5. Dry-seed measurements, length 0.817, width 0.577, thickness 0.491 cm. Thickness 0.849 of width. Seeds round. Color of seeds fleshy white (*12, p. 9*). (Figs. 24–42; 29–7.) Late maturity.

Blue Pod, No. 102

Plant short trailing, much branched, erect, height 110 cm, nodes 17–20. Leaves small, short pointed. Mature pods often tinged purple, straight to reflex curved, medium texture, round, length 9.430, width 0.768 cm. Seeds per pod 6.5. Apex abrupt. Spur not marginal, curved, length 0.762 cm. Dry seeds oval, ends round, length 0.807, width 0.553, thickness 0.451 cm. Thickness 0.816 of width. Seeds round, 7,158 seeds per 1,000 g. Color fleshy white (*12, p. 9*) veined. (Figs. 24–44; 29–9 and 10.) Very late, productive, resistant to anthracnose. From Lompoc Produce Co., Lompoc, Calif.

VARIETIES WITH COLORED SEEDS

Red Kidney, No. 116

Plants strictly bush, height 46–50 cm, nodes 6 to 7. Leaves and stems green throughout. Leaves large, long pointed. Flowers, standard lilac (*12, p. 176, 1–2*). Mature pods often splashed red, coarse, straight, length 12.572, width 1.064 cm. Seeds per pod 4.2. Apex slightly elongated. Spur not marginal, straight, length 1.241 cm. Dry seeds reniform, ends round, length 1.563, width 0.725, thickness 0.567 cm. Thickness 0.782 of width. Seeds intermediate; 2,539 seeds per 1,000 g. Color garnet brown (*12, p. 164*). (Figs. 24–45; 30–1.) Late, medium productivity, anthracnose resistant, blight susceptible. From New York (Cornell) Agricultural Experiment Station, Ithaca, N. Y.

Selection 123

Similar to Red Kidney but seeds flat. Mature pods, length 12.119, width 1.061 cm. Seeds per pod 3.9. Spur length 1.309 cm. Dry seeds, length 1.590, width 0.782, thickness 0.516 cm. Thickness 0.659 of width; 2,193 seeds per 1,000 g.

Dark Red Kidney, No. 149

Similar to Red Kidney but seeds plum violet (*12, p. 172, 4*) and earlier in maturity. Pod measurements, length 12.27, width 1.154 cm. Spur length 1.290 cm. Seeds per pod 3.9. Seed length 1.573, width 0.761, thickness 0.568 cm. Thickness 0.747 of width. Susceptible to anthracnose. From Michigan State College of Agriculture and Agricultural Experiment Station.

Long Yellow, No. 124

Plants strictly bush, height 44–46 cm, nodes 5–6. Leaves and stems green throughout. Leaves large, long pointed. Flowers, standard lilac (*12, p. 176–3, 4*), wings lilac (*12, p. 176–1, 2*). Mature pods not colored, coarse, slightly curved, length 12.405, width 0.908 cm. Seeds per pod 4.9. Apex slightly elongated. Spur not marginal, straight, length 1.363 cm. Dry seeds, subreniform; length 1.387, width 0.706, thickness 0.537 cm. Thickness 0.760 of width; 2,757 seeds per 1,000 g. Seed color chamois (*12, p. 325–1, 2*), eye color raw umber (*12, p. 301*), hilum ring Roman ocher (*12, p. 327*). (Figs. 24–46; 30–2.) Very early, medium productivity, resistant to anthracnose. From New York (Cornell) Agricultural Experiment Station, Ithaca, N. Y.

Improved Goddard, No. 139

Plants strictly bush, height 42–44 cm, nodes 6–7. Leaves and stems green throughout. Leaves large, long pointed. Flowers, standard lilac (*12, p. 176–3, 4*), wings lilac (*12, p. 176–1, 2*). Mature pods splashed red, coarse, slightly curved, length 13.116, width 1.051 cm. Seeds per pod 4.1. Spur marginal, straight, length 1.572 cm. Dry seeds reniform, ends round, length 1.583, width 0.798, thickness 0.554. Thickness 0.694 of width. Seeds flat. 2,863 seeds per 1,000 g. Color flesh (*12, p. 67–1*) mottled garnet brown (*12, p. 164–4*), eye Roman ocher (*12, p. 327*). No distinct hilum ring. (Figs. 24–47; 30–3.) Very early, medium productivity, anthracnose resistant, blight susceptible. From New York (Cornell) Agricultural Experiment Station, Ithaca, N. Y.

Emperor of Russia, No. 111

Plant strictly bush. Pod measurements, length 12.034, width 0.781 cm. Spur length 1.415 cm. Seed per pod 5.2. Seeds reniform, length 1.415, width 0.620, thickness 0.539 cm. Thickness 0.869 of width. Seeds round. Color of seeds tan (*12, p. 317–1, 2*) heavily mottled madder brown (*12, p. 334, 1–2*). From Sweden.

Brown Norwegian, No. 133

Plants strictly bush, height 40–42 cm, nodes 5–6. Leaves and stems green throughout. Leaves large, long pointed. Flowers, standard lilac (*12, p. 176–3, 4*) wings lilac (*12, p. 176–1, 2*). Mature pods not colored, coarse, dehisce readily, slightly curved, round, length 12.267, width 0.900 cm. Seed per pod 4.5. Spur marginal, length 1.37 cm. Dry seeds reniform, ends round, length 1.389, width 0.678, thickness 0.548 cm. Thickness 0.807 of width 3,047 seeds per 1,000 g. Color, Roman ocher (*12, p. 327–3, 4*), stippled dark brown, eye snuff brown (*12, p. 303*), hilum ring Roman ocher (*12, p. 327*). (Figs. 24–49; 30–5.) Early, medium productivity. From Central Experimental Farms, Ottawa, Canada, under Ottawa No. 71.

Selection 140

Similar to Brown Norwegian but seeds are not stippled dark brown. Mature pods not colored, coarse, dehisce readily, distinctly curved, length 11.563, width 0.881 cm. Seeds per pod, 4.7. Apex elongated. Spur marginal, length 1.328 cm. Dry seeds reniform, ends round, length 1.339, width 0.681, thickness, 0.561 cm. Thickness 0.822 of width. Seeds round. 2,746 seeds per 1000 g. Color Roman ocher (*12, p. 327–3, 4*), eye snuff brown (*12, p. 303*), hilum ring Roman ocher (*12, p. 327*). (Figs. 24–48; 30–4.) Early, medium productivity, susceptible to anthracnose and blight. From Owosso, Mich.

Selection 150

Similar to Selection 140 except seeds without eye markings and pods distinctly sickle-shaped. Pod length 12.540, width 0.865 cm. Seeds per pod, 5.1. Spur length 1.128 cm. Dry seeds, length 1.361, width 0.673, thickness 0.552 cm. Thickness 0.819 of width. (Figs. 24–50; 30–6.)

Selection 141

Similar to Selection 140 except pods are shorter, length 9.820, width 0.913 cm. Spur length 1.448. Pods distinctly sickle-shaped. Seeds per pod 4.1. Dry seeds, length 1.228, width 0.687, thickness 0.536 cm. Thickness 0.794 of width; 2,940 seeds per 1000 g. (Figs. 24–51; 30–7.)

Selection 161

Similar to Selection 140 except pods are straight. Seeds per pod 5–6. Spur not marginal. Seeds less reniform and eye marking less distinct. (Figs. 24–52; 30–8.)

Selection 156

Plants strictly bush, height 35–38 cm, nodes 6–7. Leaves and stems green throughout. Leaves large, dark green. Flowers white. Mature pods not colored, coarse, curved, flattened, length 9.589, width 1.082 cm. Seeds per pod 4.2. Apex slightly elongated. Spur not marginal, curved length 1.235 cm. Dry seeds reniform, ends round, length 1.072, width 0.652, thickness 0.568 cm.

Thickness 0.870 of width. 2,633 seeds per 1,000 g. Color of seed Naples yellow (*12, p. 29–1*). (Figs. 24–53; 30–9.) Early, low productivity. From Madawaska, Canada.

Eureka, No. 130

Plant strictly bush, height 42–44 cm, nodes 6–7. Leaves and stems green throughout. Leaves large oval, blunt pointed, crumpled. Flowers standard lilac (*12, p. 176–3, 4*), wings lilac (*12, p. 176–1, 2*). Mature pods not colored, coarse, straight, round, length 8.902, width 1.104 cm. Seeds per pod 4.6. Apex abrupt. Spur not marginal, straight, length 0.852 cm. Dry seeds, length 0.893, width 0.691, thickness 0.611 cm. Thickness 0.884 of width. Seeds spherical; 3,772 seeds per 1,000 g. Color Naples yellow (*12, p. 29–1*). (Figs. 24–54; 31–1). Medium late, medium productivity, anthracnose and blight resistant. From New York (Cornell) Agricultural Experiment Station, Ithaca, N. Y., and from growers in Washington County, Minn.

Brown Swedish, No. 144

Plant strictly bush, height 40–42 cm, nodes 6–7. Leaves and stems green throughout. Leaves large, long pointed. Flowers, standard lilac (*12, p. 176–3, 4*), wings lilac (*12, p. 176–1, 2*). Mature pods not colored, coarse, dehisce readily at maturity. Distinctly curved, round, length 8.902, width 1.104 cm. Seeds per pod 4.6. Apex slightly elongated. Spur not marginal, straight, length 0.852 cm. Dry seeds oval, ends round, length 1.064, width 0.706, thickness 0.609 cm. Thickness 0.862 of width. 3,018 seeds per 1,000 g. Color Roman ocher (*12, p. 327–3, 4*), eye snuff brown (*12, p. 303*), hilum ring Roman ocher (*12, p. 327*). (Figs. 24–55; 31–2.) Early medium productivity, susceptible to anthracnose and blight. From Northrup, King & Co., Minneapolis, Minn.

Selection 135

Similar to Brown Swedish, except pods straight with long spur and seeds stippled dark brown. Dry pods, length 10.46, width 0.955 cm. Spur length 1.523. Dry seeds, length 1.312, width 0.700, thickness 0.500 cm. Thickness 0.714 of width. (Figs. 24–56; 31–3.) From Sweden.

Selection 145

Similar to Brown Swedish except pods less curved. Dry pods, length 9.177, width 0.906 cm. Spur length 1.07 cm. Dry seeds, length 1.31, width 0.721, thickness, 0.589 cm. Thickness 0.816 of width. Seeds round. (Figs. 24–57; 31–4.)

China Red Eye, No. 151

Plant strictly bush, height 28–30 cm, nodes 5–6. Leaves and stems green throughout. Flowers white. Mature pods not colored. Coarse, straight, length 11.367, width 1.084 cm. Seeds per pod 4.9. Apex slightly elongated. Spur not marginal, curved, length 1.178 cm. Dry seeds oval, length 1.286, width 0.769, thickness 0.630 cm. Thickness 0.922 of width. 2,092 seeds per 1,000 g. Color white with ox-blood red (*12, p. 94*) irregular mottled pattern around eye covering approximately one-fourth of entire surface of seed. Eye markings lacking. (Figs. 24–58; 31–5.) Very early, low productivity, susceptible to anthracnose and blight. From New York (Cornell) Agriculture Experiment Station, Ithaca, N. Y.

Old Fashioned Yellow Eye, No. 125

Plant strictly bush, height 50–52 cm, nodes 6–7. Leaves and stems green throughout. Flowers white. Mature pods not colored, coarse, slightly curved, length 10.493, width 1.154 cm. Seeds per pod, 4.4. Spur not marginal, curved, length 1.206 cm. Dry seeds, length, 1.23, width 1.799, thickness 0.679 cm. Thickness 0.848 of width. 2,294 seeds per 1,000 g. Color white with irregular yellow ocher (*12, p. 326–4*), pattern around hilum covering approximately one-fourth of area of seed. Eye snuff brown (*2, p. 303*) with white spot on each side of hilum. (Figs. 24–59; 31–6.) Medium early, medium productivity, resistant to anthracnose and blight. From various sources.

Arikara Yellow, No. 117

Plant short trailing, decumbent, not highly branched, height 75 to 80 cm, nodes 15–16. Leaves and stems green throughout. Leaves medium size, broad short pointed. Flowers white. Mature pods not colored, papery texture, curved, length 9.695, width 0.990 cm. Seeds per pod, 5.4. Apex abrupt. Spur marginal, curved, length 0.918 cm. Dry seeds reniform; length 1.302, width 0.711, thickness 0.454 cm. Thickness 0.624 of width. Seeds flat; 3,983 seeds per 1,000 g. Color raw sienna (*12, p. 329–1, 2*). No eye markings. (Figs. 24–60; 31–7.) Medium early, productive, resistant to anthracnose and blight. From Oscar Will Seed Co., Bismarck, N. Dak., under the name given. Also received under name of Yellow Indian. Resembles most Great Northern except in seed color.

Black Turtle Soup, No. 118

Plant short trailing, erect, height 58–60 cm, nodes 13–14. Leaves medium size, dark green. Stems more or less purple. Flowers, standard magenta (*12, p. 182–2*), wings violet rose (*12, p. 154–2*). Mature pods often tinged purple, medium coarse, distinctly curved near free end, length 10.379, width 0.791 cm. Seeds per pod, 5.4. Apex abrupt. Spur marginal, straight, length 1.025 cm. Dry seeds reniform; flat length 1.040, width 0.597, thickness 0.393 cm. Thickness 0.656 of width. Seeds flat; 5,332 seeds per 1,000 g. Color violet black (*12, p. 347–4*). (Figs. 24–61; 31–8.) Late, very productive, very resistant to anthracnose, susceptible to blight.

Hidatsa Red, No. 131

Plant short trailing, height 75 to 90 cm, nodes 23–26. Leaves and stems green throughout. Leaves large, short pointed, very pubescent. Flowers white. Mature pods not colored, papery texture, curved, flat, length 9.00, width 1.03 cm. Seeds per pod, 5.4. Apex abrupt. Spur marginal, curved, length 0.730 cm. Dry seeds not reniform, truncated, length 1.444, width 0.764, thickness 0.535 cm. Thickness 0.699 of width. Seeds flat; 3,320 seeds per 1,000 g. Color plum violet (*12, p. 172–4*), no eye marking. (Figs. 25–71; 32–7.) Very late, low productivity, susceptible to anthracnose. Not well adapted in north central United States. From Oscar Will Seed Co., Bismarck, N. Dak., under name given. Also received under name of Red Indian.

Selection 128

Similar to Hidatsa Red, No. 131. Height 70–75 cm, nodes 17–20. Mature pods, length 8.668, width 0.993 cm. Seeds per pod 5. Spur length 0.911 cm. Dry seeds, length 1.139, width 0.706, thickness 0.481 cm. Thickness 0.681 of width; 4,750 seeds per 1,000 g. (Figs. 25–72.) Very susceptible to anthracnose. Medium late, medium productivity, adapted to north central United States.

Selection 147

Plant short trailing, height 75 to 120 cm, nodes 13–17. Leaves and stems green throughout. Leaves medium size, short pointed. Flowers white. Mature pods often splashed red, papery texture, curved, flat, length 10.479, width 1.143 cm. Seeds per pod, 4.6. Apex abrupt. Spur marginal, curved, length 1.136 cm. Dry seeds not reniform; length 1.178, width 0.801, thickness 0.517 cm. Thickness 0.645 of width. 3,055 seeds per 1,000 g. Color of seeds snuff brown (*12, p. 303*). No eye marking. (Figs. 25–74; 32–8.) Medium early, productive, resistant to anthracnose. Adapted to north central United States.

Selection 142

Plant short trailing, height 70–75 cm, nodes 14–15. Leaves and stems green throughout. Leaves medium size, broad, short pointed. Flowers white. Mature pods slightly splashed red, papery texture, curved, flat, length 9.712, width 0.965 cm. Seeds per pod, 5.0. Apex abrupt. Spur marginal, curved. Length 0.849 cm. Dry seeds reniform, length 1.33, width 0.724, thickness 0.496 cm. Thickness 0.683 of width. Seeds flat; 3,165 seeds per 1,000 g. Color dull purple lake (*12, p. 170–3, 4*), stippled white. No eye marking. (Figs. 24–62; 31–9.) Late, medium productivity, resistant to anthracnose. Most nearly resembles Hansen, the variety in which it occurred.

Zebra, No. 126

Plant short trailing, height 60–65 cm, nodes 16–17. Leaves dark green, medium size, short pointed. Stems purple. Flowers, standard magenta (*12, p. 182–2*), wings violet rose (*12, p. 154–2*). Mature pods splashed purple, medium texture, curved, flat, length 8.847, width 0.907 cm. Seeds per pod 5. Spur marginal, curved, length 0.817 cm. Dry seeds reniform, truncated, length 1.158, width 0.709, thickness 0.494 cm. Thickness 0.696 of width. Seeds flat; 4,018 seeds per 1,000 g. Color smoke gray (*12, p. 363*), longitudinal black stripes, eye black, no hilum ring marking. (Figs. 24–63; 31–10.) Late, medium productivity, slightly susceptible to anthracnose. Indian booth, South Dakota State fair, and grocery store, Gonvick, Minn.

Hansen, No. 122

Plant short trailing, height 70–80 cm, nodes 17–18. Leaves and stems green throughout. Leaves medium size, short pointed. Flower color, standard and wings pale reddish lilac (*12, p. 131–1*). Mature pods not colored, medium texture, curved, flat, length 9.392, width 1.001 cm. Seeds per pod 5.4. Apex abrupt. Spur marginal, curved, length 0.854 cm. Dry seeds, length 1.141, width 0.718, thickness 0.484 cm. Thickness 0.674 of width. Seeds flat; 4,296 seeds per 1,000 g. Color background stone (*12, p. 312*) tinged lilac mauve (*12, p. 196*), striped with longitudinal violet (vinous mauve, *12, p. 184*) bands. (Figs. 24–64; 32–1.) Late, productive, susceptible to anthracnose. Adapted to the north central part of the United States. Described by Freeman. From the Arizona Agriculture Experiment Station, Tucson, Ariz.

Selection 148

Plant short trailing, decumbent, height 70–75 cm, nodes 17–18. Leaves dark green; stems with considerable purple color. Flower color, standard magenta (*12, p. 182–2*), wings violet rose (*12, p. 154–2*). Mature pods splashed purple, medium texture, curved, length 9.582, width 0.973 cm. Apex abrupt. Spur marginal, curved, length 0.927 cm. Dry seeds subreniform, truncated, length 1.251, width 0.734, thickness 0.502 cm. Thickness 0.682 of width. Seeds flat, 3,929 seeds per 1,000 g. Color pale yellowish flesh (*12, p. 68–2*), mottled black. No eye markings. (Figs. 24–65; 32–2.) Late, medium productivity. Susceptible to anthracnose. Selected from a lot of beans secured from the Sisseton Indian Reservation, S. Dak.

Garaypata, No. 127

Plant short trailing, decumbent habit, height 60–65 cm, nodes 16–17. Leaves and stems green throughout. Flowers white. Mature pods splashed red, medium texture, curved, length 9.144, width 0.941 cm. Seeds per pod 4.9. Apex abrupt. Spur not marginal, curved, length 0.942. Dry seeds subreniform; length 1.205, width 0.724, thickness 0.498 cm. Thickness 0.688 of width. 3,930 seeds per 1,000 g. Color salmon flesh (*12, p. 138–2*), mottled snuff brown (*12, p. 303*). Eye color raw sienna (*12, p. 329–1, 2*). (Figs. 24–66; 32–3.) Late, medium productivity, susceptible to anthracnose. Described by Freeman (*5*). Known commercially as Pinto. From Arizona Agricultural Experiment Station, Tucson, Ariz., and several other locations, including the Dakotas.

Mottled Red Indian, No. 157

Plant short trailing, height 50–66 cm, nodes 24–26. Leaves and stems green throughout. Leaves dark green, broad, short, pointed, highly pubescent. Flowers white. Mature pods not colored, papery texture, markedly curved, flat, length 9.001, width 1.030 cm. Seeds per pod 4.6. Spur marginal, curved, length 0.730 cm. Dry seeds subreniform; length 1.444, width 0.764, thickness 0.535 cm. Thickness 0.699 of width. Seeds flat; 4,347 seeds per 1,000 g. Color plum violet (*12, p. 172–4*) and white in irregular pattern. No eye markings. (Fig. 24–67.) Very late, low productivity, susceptible to anthracnose. Not adapted to north central United States. From A. B. Shoemaker, Modesto, Calif. Snyonym Spotted Red Indian.

Bayou Chico, No. 158

Plant short trailing, height 70–72 cm, nodes 19–20. Leaves and stems green throughout. Leaves small, short pointed. Flowers white. Mature pods not colored, papery in texture, curved, length 9.025, width 0.888 cm. Seeds per pod 5.2. Apex abrupt. Spur marginal, curved, length 0.933 cm. Dry seeds reniform, length 1.083, width 0.674, thickness 0.471 cm. Thickness 0.697 of width. 4,616 seeds per 1,000 g. Color raw sienna (*12, p. 329–1, 2*). No eye marking. (Figs. 24–68; 32–4.) Medium early, medium productivity, highly susceptible to anthracnose. From Arizona Agricultural Experiment Station, Tucson, Ariz., and Germaine Seed Co., Los Angeles, Calif.

Bayou Grande, No. 159

Plant short trailing, height 45–50 cm, nodes 10–11. Leaves and stems green throughout. Leaves large, highly pubescent, blunt pointed. Flowers, standard lilac (*12, p. 176–3, 4*), wings lilac (*12, p. 176–1, 2*). Mature pods often splashed red, wrinkled surface, curved, length 11.40, width 0.960 cm. Seeds per pod 4.9. Apex abrupt. Spur marginal, straight, length 0.806 cm. Dry seeds reniform, length 1.323, width 0.804, thickness 0.768 cm. Thickness 0.768 of width. 2,272 seeds per 1,000 g. Color pale pink (*12, p. 135–2*), eye Roman ocher (*12, p. 327*), with snuff brown (*12, p. 303*) hilum ring. Seed color changes to yellow and brown with age or exposure. (Figs. 24–69; 32–5.) Very late, low productivity, susceptible to anthracnose. Not adapted to north central United States. From Germaine Seed Co., Los Angeles, Calif.

Pink, No. 160

Plant short trailing, height 45–50 cm, nodes 22. Leaves and stems green throughout. Leaves large. Flowers white. Mature pods not colored, curved, flat, length 8.862, width 1.060 cm. Seeds per pod 5.2. Apex abrupt. Spur marginal, curved, length 0.804 cm. Dry seeds reniform; length 1.222, width 0.746, thickness 0.550 cm. Thickness 0.737 of width; 4,854 seeds per 1,000 g. Color hydrangea pink (*12, p. 132*). Not distinctly eyed. (Fig. 25–79.) Very late, susceptible to anthracnose and bean rust. Not adapted to north central United States. From Germaine Seed Co., Los Angeles, Calif.

Wild Goose, No. 121

Plant short trailing, height 60–65 cm, nodes 16–17. Leaves dark green, medium size, blunt pointed. Stems with considerable purple color. Flowers, standard magenta (*12, p. 182–2*), wings reddish violet (*12 p. 180–1*). Mature pods splashed purple, medium texture, straight, round, length 7.958, width 0.977 cm. Seeds per pod 5.4. Apex abrupt. Spur marginal, curved, length 0.780 cm. Dry seeds not reniform, truncated, length 0.874, width 0.661, thickness 0.502 cm. Thickness 0.759 of width. 5,090 seeds per 1,000 g. Color flesh (*12, p. 67–1*) mottled sepia (*12, p. 300*), not distinctly eyed. (Figs. 24–70; 32–6.) Late, productive, resistant to anthracnose and blight. Selected out of Garaypata. Seed obtained as a mixture in Garaypata and later without admixture under the name given.

Improved Yellow Eye, No. 120

Plants short trailing, height 75–80 cm, nodes 11–12. Mature pods curved, length 9.764, width 1.028 cm. Seeds per pod 4.8. Spur not marginal, curved, length 1.021 cm. Dry seeds, length 1.133, width 0.737, thickness 0.634 cm. Thickness 0.860 of width. Seeds round; 2,572 seeds per 1,000 g. Color white with yellow ocher (*12, p. 326–4*), pattern around hilum covering approximately one-third of entire area. Eye snuff brown (*12, p. 303*) with yellow ocher hilum ring. (Figs. 25–75; 32–9.)

Ruby Horticultural Bush, No. 129

Plant short trailing, similar to Vineless Marrow. Height 75–80 cm, nodes 11 to 12. Leaves and stems green throughout. Leaves medium size, long pointed. Flowers, standard lilac (*12, p. 176–3, 4*), wings lilac (*12, p. 176–1, 2*). Mature pods splashed red, coarse, slightly curved, length 10.217, width 1.070 cm. Seeds per pod 3.8. Apex elongated. Spur marginal, curved, length 1.617

cm. Dry seeds oval, length 1,203, width 0.786, thickness 0.642 cm. Thickness 0.816 of width. 2,281 seeds per 1,000 g. Color flesh (*12, p. 139–1*) with large irregular splashes of garnet brown (*12, p. 164–4*), eye Roman ocher (*12, p. 327*). No distinct hilum ring. (Figs. 25–76; 32–10.) Medium early, productive, susceptible to anthracnose, resistant to blight. From Northrup, King & Co., Minneapolis, Minn.

DISCUSSION

In Table 5 are listed the 43 named varieties and 22 selections of field beans that have been distinguished and classified. Of these, 20 named varieties and 10 selections have white seeds and 23 named varieties and 13 selections have colored seeds.

From the large collection grown it was possible to identify practically all of the field varieties of common beans previously classified and described. Distinct varieties not previously classified and described have been given the names under which they occurred most frequently. Great Northern and Arikara Yellow are the most important of these and Zebra another, probably somewhat less important. One new variety which has several characteristics that may make it valuable in some of the field-bean-growing districts was selected out of the variety Garaypata. It was later obtained in pure form under the name Wild Goose.

In making up the key to the varieties and selections, morphological characters that are stable under varying conditions were employed as far as possible. Therefore the key should be useful in identifying varieties within narrow limits under widely different environments.

Yield data have been secured for practically all the named varieties and for many of the selections. These data have not been used in the classification but serve to indicate the value of the varieties and selections under the environmental conditions prevailing during the seasons in which they were grown.

TABLE 5.—*Index to varieties of field beans*

Variety name	Minnesota variety or selection No.	Description page	Illustrations of—	
			Seeds	Pods
			Figure	*Figure*
Arikara Yellow	117	45	24–60	31– 7
Bayou Chico	158	47	24–68	32– 4
Bayou Grande	159	42	24–69	32– 5
Black Turtle Soup	118	46	24–61	31– 8
Blue Pod	102	42	24–44	29–9, 10
Brown Norwegian	133	43	24–49	30– 5
Selection	140	43	24–48	30– 4
Do	150	43	24–50	30– 6
Do	141	43	24–51	30– 7
Do	161	43	24–52	30– 8
Brown Swedish	144	44	24–55	31– 2
Selection	135	44	24–56	31– 3
Do	145	44	24–57	31– 4
Burlingame	80	40	23–26	27– 10
Selection	154	40	23–28	28– 2
California Wonder	91	40	23–24	27– 8
China Red Eye	151	44	24–58	31– 5
Dark Red Kidney	149	42	----	----
Emperor of Russia	132	43	----	----
Eureka	130	44	24–54	31– 1
French Dwarf Kidney	115	29	23– 7	26– 4
French Dwarf Rice	101	----	24–41	29– 6
French White	98	40	23–32	28– 6
Garaypata	127	46	24–66	32– 3
Great Northern	78	30	23–12	27– 1
Selection	97	32	23–13	27– 2
Do	85	32	23–16	27– 3
Hansen	122	46	24–64	32– 1
Selection	142	45	24–62	31– 9
Do	148	46	24–65	32– 2
Haricot	103	29	23–10	26– 7
Selection	162	29	23–11	26– 8
Hidatsa Red	131	45	25–71	32– 7
Selection	128	45	25–72	----
Do	147	45	25–74	32– 8
Improved Goddard	139	43	24–47	30– 3
Improved Yellow Eye	120	47	25–75	32– 9
Lady Washington	82	32	23–18	27– 4
Selection	106	32	23–19	27– 5

TABLE 5.—*Index to varieties of field beans*—Continued

Variety name	Minnesota variety or selection No.	Description page	Illustrations of—	
			Seeds	Pods
			Figure	*Figure*
Long Yellow	124	42	24–46	30– 2
Mottled Red Indian	157	46	24–67	
Navy Pea	94	41	24–36	29– 1
Selection	111	42	24–43	29– 8
Do	112	42	24–42	29– 7
Old-Fashioned Yellow Eye	125	44	24–59	31– 6
Pearce Improved	70	40	23–25	27– 9
Pilot	83	32	23–22	
Pink	160	47	25–79	
Red Kidney	116	42	24–45	30– 1
Selection	123	42		
Robust	76	41	24–40	29– 5
Ruby Horticultural Bush	129	47	25–76	32– 10
Selection	156	43	24–53	30– 9
Do	90	29	23– 9	26– 6
Snowflake	75	41	24–37	29– 2
Selection	152	41	24–38	29– 3
Vineless Marrow	79	41	23–35	28– 9
White Kidney	104	29	23– 8	26– 5
White Marrow	87	41	23–33	28– 7
Selection	100	41	23–34	28– 8
White Wonder	92	40	23–30	28– 5
Selection	81	40	23–31	28– 4
Wild Goose	121	47	24–70	32– 6
Wolverine (see Snowflake)	110		24–39	29– 4
Yankee Winter	107	32	23–23	27– 7
Zebra	126	46	24–63	31– 10

LITERATURE CITED

(1) ANONYMOUS.
1920. DWARF FRENCH BEANS AT WISLEY, 1919. Jour. Roy. Hort. Soc. 45: 316–333.

(2) BAILEY, L. H.
1914. BEAN. *In* his Standard Cyclopedia of Horticulture, v. 1, p. 458–463, illus. New York and London.

(3) BURR, F., JR.
1865. THE FIELD AND GARDEN VEGETABLES OF AMERICA: CONTAINING FULL DESCRIPTIONS OF NEARLY ELEVEN HUNDRED SPECIES AND VARIETIES; WITH DIRECTIONS FOR PROPAGATION, CULTURE, AND USE. . . . 667 p., illus. Boston.

(4) EMERSON, R. A.
1916. A GENETIC STUDY OF PLANT HEIGHT IN PHASEOLUS VULGARIS. Nebr. Agr. Expt. Sta. Research Bul. 7, 73 p., illus.

(5) FREEMAN, G. F., JAFFA, A., and DE ONG, E. R.
1912. SOUTHWESTERN BEANS AND TEPARIES. Ariz. Agr. Expt. Sta. Bul. 68, p. [573]–619, illus.

(6) HENDRY, G. W.
1918. BEAN CULTURE IN CALIFORNIA. Calif. Agr. Expt. Sta. Bul. 294, p. [287]–347, illus.

(7) IRISH, H. C.
1901. GARDEN BEANS CULTIVATED AS ESCULENTS. Missouri Bot. Gard. Rpt. 12: 81–165, illus.

(8) JARVIS, C. D.
1908. AMERICAN VARIETIES OF BEANS. N. Y. Cornell Agr. Expt. Sta. Bul. 260, p. 149–255, illus.

(9) LEACH, J. G.
1923. THE PARASITISM OF COLLETOTRICHUM LINDEMUTHIANUM. Minn. Agr. Expt. Sta. Tech. Bul. 14, 41 p., illus.

(10) MARTENS, G. VON.
1869. DIE GARTENBOHNEN. IHRE VERBREITUNG, CULTUR UND BENÜTZUNG. Ausgabe 2, vermehrte, 105 p., illus. Ravensburg.

134657—32——4

(11) SHAW, J. K., and NORTON, J. B.
1918. THE INHERITANCE OF SEED COAT COLOR IN GARDEN BEANS. Mass. Agr. Expt. Sta. Bul. 185, p. [59]–104.

(12) SOCIÉTÉ FRANÇAISE DES CHYRSANTHÉMISTES, and OBERTHÜR, R., with the principal collaboration of DAUTHENAY, H.
1905. REPERTOIRE DE COULEURS POUR AIDER À LA DÉTERMINATION DES COULEURS DES FLEURS, DES FEUILLAGES ET DES FRUITS. 82 p., illus. [text] Rennes and Paris. [Text and 2 volumes of plates bound separately.]

(13) TRACY, W. W., JR.
1907. AMERICAN VARIETIES OF GARDEN BEANS. U. S. Dept. Agr., Bur. Plant Indus. Bul. 109, 160 p., illus.

(14) ZAVITZ, C. A.
1915. FIELD BEANS. Ontario Dept. Agr., Bul. 232, 15 p., illus.

THE INFLUENCE OF CERTAIN BALANCED RATIONS ON THE CHEMICAL AND PHYSICAL PROPERTIES OF MILK FAT[1]

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INTRODUCTION

Many results are given in the literature dealing with milk fat which show the effects of different feeds for dairy cows upon the milk fat produced. Amberger (*1*)[2] found that the feeding of beets caused an appreciable lowering of the iodine number and an increase in the Reichert-Meissl and Polenske numbers. When sucrose was substituted for the beets the changes were similar in direction but not so great. Amberger also found that when malt germs were fed, the Reichert-Meissl number was reduced from 25.48 to 16.70 and the iodine number was increased from 32.1 to 39.2. Siegfeld (*14*, *15*), Fritzsche (*8*), and Luhrig, Hepner, and Blau (*13*), studied the influence of beet leaves and tops on the composition of milk fat. Their results showed that the Reichert-Meissl, Polenske, and saponification numbers of the fat were increased while the iodine number and the index of refraction were lowered. Zaitschek (*17*) found that cows on a turnip ration produced fat having higher Reichert-Meissl and saponification numbers than when on dry feed, and that potatoes acted similarly to turnips. Boes and Weyland (*4*) fed a ration of sugar beets exclusively. The fat produced gave the following results: Reichert-Meissl number 28.16, Polenske number 6.16, saponification number 234.2, and iodine number 24.22. Kieferle (*10*) showed that the feeding of silage gave a considerable increase in the Reichert-Meissl number and a slightly higher Polenske number.

Lindsey, Holland, and Smith (*12*) state that soybean meal caused no marked difference in milk fat except a slight increase in the unsaturated acids. Soybean oil, however, caused the saponification number to drop from 231.59 to 221.65, and the Reichert-Meissl from 27.05 to 23.27. The iodine number on the other hand increased from 31.90 to 40.25. Cranfield (*5*) worked with coconut cake and linseed cake and Cranfield and Taylor (*6*) with linseed cake and hempseed cake. They showed that when cows were removed from poor pasture to well-balanced rations containing these products a considerable rise in the Reichert-Meissl, Kirschner, and Polenske numbers and a fall in the index of refraction occurred. Smith, Wells, and Ewing (*16*) report that the feeding of cottonseed oil lowered the saponification number and the soluble fatty acids and increased the insoluble fatty acids. Eckles and Palmer (*7*) showed that cottonseed products in the ration decreased the saponification and Reichert-Meissl numbers

[1] Received for publication July 10, 1931; issued August, 1932. Presented before the Division of Agricultural and Food Chemistry at the eighty-first meeting of the American Chemical Society, Indianapolis, Ind., Mar. 30 to Apr. 3, 1931.

[2] Reference is made by number (italic), to Literature Cited, p. 57.

and increased the iodine number, while Geisler (*9*) states that cottonseed feeding gave higher Reichert-Meissl and iodine numbers and a lower Polenske number.

It should be noted that much of the work reported on the effects of feeds upon milk fat has dealt with rations which may be considered abnormal in some respect. For example, rations made up solely of sugar beets, silage, etc., and those to which appreciable amounts of oil, such as cottonseed or soybean oil, have been added are not typical rations for the dairy herd.

The purpose of this investigation was to study the effect on milk fat of different grain mixtures each of which was a normal balanced feed.

GENERAL PLAN OF THE WORK

Three groups of cows were selected, each group producing about 200 pounds of milk daily. These groups were made up as shown in Table 1.

TABLE 1.—*Breed, age, calving, and milk-production data for cows in the various groups*

Animal No.	Breed	Age on Nov. 1, 1930	Date of last calving	Approximate milk daily on Nov. 1, 1930
		Y. M. D.	*1930*	*Pounds*
GROUP 1				
370	Holstein	6 6 15	Jan. 18	35
355	do	6 3 27	Aug. 21	46
403	do	4 9 13	May 27	45
406	do	4 4 15	Oct. 18	45
428	do	2 10 15	Mar. 18	32
GROUP 2				
423	Holstein	3 5 15	Oct. 23	45
431	do	2 11 18	Apr. 5	28
432	do	2 9 28	Apr. 10	25
437	do	2 9 25	June 8	37
438	do	2 9 7	June 14	30
440	do	2 7 28	July 24	33
442	do	2 0 13	July 13	18
GROUP 3				
395	Brown Swiss	8 1 15	May 5	34
408	Jersey	3 11 26	Apr. 2	20
412	Guernsey	6 10 7	Aug. 1	25
416	Ayrshire	3 5 27	Aug. 14	28
436	Jersey	2 9 17	Apr. 29	18
439	Brown Swiss	2 11 28	June 15	22
443[a]	Guernsey	2 5 21	Sept. 18	15
444[a]	Ayrshire	2 6 23	Oct. 18	25

[a] Nos. 443 and 444 were dropped from the experiment Dec. 4, 1930, because of the development of a bad flavor in the milk.

Special grain mixtures were made up so that about 50 per cent of the total protein of the mixture was supplied by a high protein feed. Otherwise, each mixture was the same except for a small difference in the percentage of corn. The three special mixtures used were as follows:

Special herd mixture A

	Per cent		Per cent
Cottonseed meal, 43 per cent	19	Molasses	7. 5
Corn, ground	21	Bone meal	1
Barley, ground	15	Salt	1. 5
Oats, ground	20		
Wheat, ground	15		100. 0

Special herd mixture B

	Per cent		Per cent
Linseed meal	24	Molasses	7. 5
Corn, ground	16	Bone meal	1
Barley, ground	15	Salt	1. 5
Oats, ground	20		
Wheat, ground	15		100. 0

Special herd mixture C

	Per cent		Per cent
Soybeans (seed), ground	23	Molasses	7. 5
Corn, ground	17	Bone meal	1
Barley, ground	15	Salt	1. 5
Oats, ground	20		
Wheat, ground	15		100. 0

These mixtures were prepared by a commercial feed manufacturer according to formulas furnished to him. The percentages of total protein were calculated to be: A, 16.65; B, 16.16; and C, 16.38.

The formula for the regular herd mixture is:

	Per cent		Per cen
Barley	20	Soybean meal	5
Corn	7. 5	Wheat	5
Corn gluten feed	15	Wheat bran	15
Cottonseed meal	5	Bone meal	1
Molasses	10	Salt	1. 5
Oats	15		

This mixture contained a total protein content of 16.04 per cent.

The grain mixtures were fed in the approximate proprotion of 1 pound of the mixture for each 3 pounds of milk produced. Corn silage and good quality alfalfa hay were fed liberally throughout the experiment. There was no pasture or feed in the yard.

The experimental feeding was arranged as shown in Table 2.

TABLE 2.—*Arrangement of experimental periods and grain mixtures fed*

Period	Date	Grain mixtures fed [a]
Preliminary	Nov. 1–7, 1930	Regular herd mixture.
Transition	Nov. 8–14, 1930	Gradual change to special mixtures.
First	Nov. 15–Dec. 12, 1930	Mixtures A, B, and C.
Transition	Dec. 13–19, 1930	Mixtures A, B, and C gradually interchanged.
Second	Dec. 20, 1930–Jan. 9, 1931	Mixtures A, B, and C.
Transition	Jan. 10–16, 1931	Mixtures A, B, and C gradually interchanged.
Third	Jan. 17–30, 1931	Mixtures A, B, and C.
Transition	Jan. 31–Feb. 12, 1931	Gradual change to regular herd mixture
Fourth	Feb. 12, 1931, to end of experiment.	Regular herd mixture.

[a] Special mixtures A, B, and C were fed to the three groups of cows as follows:

	First period	Second period	Third period
Group 1	A	C	B
Group 2	C	B	A
Group 3	B	A	C

The milk produced by each group of cows was kept separate on certain days during each period of the experiment. Each lot of milk was separated with a centrifugal separator, the cream was churned, and the butter was subjected to laboratory examination.

LABORATORY PROCEDURE

Each lot of butter was melted on a warm water bath and after the water had separated by gravity the fat was decanted and filtered. The determinations reported in this paper are: (1) Index of refraction (a Zeiss butyro-refractometer was used); (2) iodine absorption number (Hanus method); (3) saponification number (Koettstorfer number); (4) soluble acids; (5) insoluble acids (Hehner number); (6) Soluble volatile acids (Reichert-Meissl number); (7) insoluble volatile acids (Polenske number); (8) Jensen-Kirschner number (determined by the method described by Leach (*11, p. 501*)); (9) free fatty acids; and (10) mean molecular weight.[3]

All determinations except where otherwise noted were made by official methods of analysis of the Association of Official Agricultural Chemists (*2*).

TABLE 3.—*Results of the examination of the milk fats produced by the three groups of cows on various rations*

GROUP 1

Date	Period	Ration	Refractive index	Iodine number	Saponification number	Soluble acids	Insoluble acids (Hehner number)	Reichert-Meissl number	Polenske number	Jensen-Kirschner number	Free fatty acids	Mean molecular weight
1930												
Nov. 7	Preliminary	Regular	1.4594	33.38	234.35	5.04	79.48	30.74	2.70	25.48	0.40	239.4
Nov. 15	Transition	Regular to A	1.4592	31.06	234.91	6.77	87.80	29.00	2.58	24.06	.37	240.0
Nov. 24	First	A	1.4592	31.02	235.32	4.60	83.06	30.54	3.00	26.29	.54	238.2
Nov. 29	do	A	1.4591	32.09	236.62	4.32	81.03	31.58	2.99	27.08	.42	237.1
Dec. 7	do	A	1.4588	30.30	236.84	3.68	77.88	26.99	3.02	21.70	1.47	236.9
Dec. 11	do	A	1.4592	32.70	234.27	4.14	75.75	31.44	2.82	25.92	.59	222.6
Dec. 18	Transition	A to C	1.4595	33.60	235.70	5.20	77.22	31.26	2.22	26.33	.59	238.0
Dec. 26	Second	C	1.4593	33.08	236.14	4.72	81.65	31.36	2.93	29.08	.66	237.6
1931												
Jan. 2	do	C	1.4601	38.57	234.26	4.89	86.88	30.94	1.79	26.66	1.01	239.5
Jan. 7	do	C	1.4600	36.46	229.94	4.08	83.12	30.40	2.42	24.78	.63	244.0
Jan. 16	Transition	C to B	1.4597	35.28	235.90	4.94	78.69	30.61	2.67	26.26	1.07	237.8
Jan. 25	Third	B	1.4600	36.40	236.24	3.16	86.60	25.96	2.26	20.90	1.60	237.5
Feb. 2	do	B	1.4597	34.28	231.16	3.42	88.41	28.18	2.59	24.42	1.01	242.7
Feb. 19	Transition	B to regular	1.4594	32.84	237.01	3.72	84.61	31.02	2.68	24.56	1.02	236.7
Feb. 25	Fourth	Regular	1.4594	32.41	236.75	4.51	86.34	31.22	2.83	27.05	2.12	237.0
Mar. 3	do	do	1.4590	31.20	236.49	4.28	82.80	30.82	2.88	26.34	1.12	237.2

GROUP 2

1930												
Nov. 7	Preliminary	Regular	1.4598	34.96	233.84	5.62	80.78	32.89	2.23	24.88	0.35	239.3
Nov. 15	Transition	Regular to C	1.4599	35.52	231.84	5.22	84.04	31.38	2.18	25.99	.33	242.0
Nov. 24	First	C	1.4599	38.12	236.53	4.91	82.44	30.06	2.19	26.56	.62	237.2
Nov. 29	do	C	1.4599	36.56	232.39	4.78	81.87	30.77	2.23	26.18	.32	241.4
Dec. 7	do	C	1.4598	36.58	234.06	3.74	80.50	28.79	2.10	23.83	.61	239.7
Dec. 11	do	C	1.4601	37.46	229.70	3.88	74.76	30.30	2.28	25.10	.63	227.0
Dec. 18	Transition	C to B	1.4598	35.94	233.20	4.73	79.32	31.36	2.13	25.94	.44	240.6
Dec. 26	Second	B	1.4597	35.52	235.94	4.66	83.86	31.44	2.83	27.85	.50	237.8

TABLE 3.—*Results of the examination of the milk fats produced by the three groups of cows on various rations*—Continued

GROUP 2—Continued

Date	Period	Ration	Refractive index	Iodine number	Saponification number	Soluble acids	Insoluble acids (Hehner number)	Reichert-Meissl number	Polenske number	Jensen-Kirschner number	Free fatty acids	Mean molecular weight
1931												
Jan. 2	do	B	1.4597	35.21	234.38	4.69	82.95	29.78	2.06	25.72	.59	239.4
Jan. 7	do	B	1.4598	35.77	231.24	4.24	81.49	29.84	2.54	24.14	.64	242.6
Jan. 16	Transition	B to A	1.4598	34.04	234.29	4.87	79.62	30.63	3.10	25.18	1.01	239.5
Jan. 25	Third	A	1.4602	36.15	230.70	4.01	84.23	27.01	2.10	21.90	1.48	243.2
Feb. 2	do	A	1.4598	33.46	231.18	3.87	87.33	29.98	2.46	25.52	.94	242.7
Feb. 19	Transition	A to regular	1.4594	32.84	236.84	4.46	86.10	31.42	2.52	25.82	.94	236.9
Feb. 25	Fourth	Regular	1.4594	32.40	235.56	4.29	85.92	30.00	2.80	25.77	2.13	238.2
Mar. 3	do	do	1.4592	32.64	235.10	4.33	84.76	31.50	2.78	27.70	.95	238.6

GROUP 3

1930												
Nov. 7	Preliminary	Regular	1.4591	29.72	237.21	6.85	84.67	28.72	3.16	21.82	0.32	236.5
Nov. 15	Transition	Regular to B	1.4589	32.13	235.36	5.66	82.23	31.96	2.93	23.58	.43	237.7
Nov. 24	First	B	1.4590	31.32	241.05	4.92	83.10	30.60	3.20	24.98	.32	232.8
Nov. 29	do	B	1.4590	30.93	238.26	4.02	80.42	30.30	3.07	27.48	.45	235.5
Dec. 7	do	B	1.4587	32.26	236.58	5.01	82.16	30.62	2.55	24.31	.96	237.1
Dec. 11	do	B	1.4588	29.34	236.72	4.66	80.68	28.78	2.94	24.70	.68	237.1
Dec. 18	Transition	B to A	1.4591	30.04	236.46	4.62	83.87	29.60	3.28	24.64	.48	237.2
Dec. 26	Second	A	1.4591	30.89	236.96	4.38	81.43	30.32	3.43	26.56	.82	236.8
1931												
Jan. 2	do	A	1.4591	31.54	235.06	4.28	84.02	29.50	2.37	25.42	.78	238.7
Jan. 7	do	A	1.4591	29.72	233.94	4.16	81.83	29.79	3.02	23.82	.40	239.8
Jan. 16	Transition	A to C	1.4595	34.50	234.47	4.68	82.28	30.32	2.55	25.52	1.04	239.3
Jan. 25	Third	C	1.4598	34.48	233.82	4.53	83.74	29.50	2.52	22.90	1.59	239.9
Feb. 2	do	C	1.4595	34.11	231.60	3.85	87.32	31.04	2.32	27.00	.40	242.2
Feb. 19	Transition	C to regular	1.4591	31.00	238.02	4.16	84.36	31.49	2.68	24.48	1.32	235.7
Feb. 25	Fourth	Regular	1.4592	32.18	237.33	4.94	85.18	32.50	2.88	27.26	.60	236.4
Mar. 3	do	do	1.4592	31.22	235.38	4.37	84.04	30.96	2.64	25.86	.96	238.4

RESULTS

The results of the determinations on each sample are given in Table 3. In each case the data are placed in the same line with the type of ration which was being fed when the sample was taken.

Table 4 gives the average values for the milk fats produced by each of the three groups of cows that were being fed each of the four grain mixtures and also the average values for all the samples taken from all groups of cows while on each of the four grain mixtures.

A study of the tabulated data shows no very great differences in the values found for the individual samples of fat produced during the feeding of the different grain mixtures. In many cases the fluctuations between individual samples produced while one mixture was being fed were greater than those between other samples produced during the feeding of different mixtures. However, an inspection of the average values shows certain rather definite tendencies. The averages for

[3] The mean molecular weight of the fat was computed by the use of the formula: Mean molecular weight $=\frac{W\times 6000}{3y}$, in which W=weight of fat used and y=ml of N/2 KOH used in the saponification, by Bolton (*3, p. 56*).

all samples (Table 4) show that the fat produced while the cows were on ration C containing ground soybeans has a higher index of refraction and iodine absorption number and a slightly higher mean molecular weight, but a lower saponification number and a lower Polenske number, than the fats produced during the feeding of the three other grain mixtures. These tendencies are in most cases apparent in the averages for the three groups of cows but are not so distinctly evident.

TABLE 4.—*Average values for the milk fats produced by the three groups of cows, and by all the cows, on various rations*

GROUP 1

Ration	Refractive Index	Iodine number	Saponification number	Soluble acids	Insoluble acids (Hehner number)	Reichert-Meissl number	Polenske number	Jensen-Kirschner number	Free fatty acids	Mean molecular weight
Regular	1.4593	32.33	235.86	4.61	82.87	30.93	2.80	26.29	1.21	237.9
A	1.4591	31.28	235.76	4.18	79.43	30.14	2.96	25.25	.76	233.7
B	1.45985	35.34	233.70	3.29	87.50	27.07	2.42	22.66	1.30	240.1
C	1.4598	36.04	233.45	4.56	82.88	30.90	2.38	26.84	.77	240.4

GROUP 2

Regular	1.4595	33.33	234.83	4.75	83.82	31.46	2.60	26.12	1.14	238.7
A	1.4600	34.80	230.94	3.94	85.78	28.50	2.28	23.71	1.21	243.0
B	1.4597	35.50	233.85	4.53	82.77	30.35	2.48	25.90	.58	239.9
C	1.4599	37.18	233.17	4.33	79.89	29.98	2.20	25.42	.54	236.3

GROUP 3

Regular	1.4592	31.04	236.64	5.39	84.63	30.73	2.89	24.98	0.63	237.1
A	1.4591	30.72	235.32	4.27	82.43	29.87	2.94	25.27	.67	238.4
B	1.4589	30.96	238.15	4.65	81.59	30.07	2.94	25.37	.60	235.6
C	1.4596	34.30	232.71	4.19	85.53	30.27	2.42	24.95	1.00	241.0

ALL COWS

Regular	1.4593	32.23	235.78	4.91	83.77	31.04	2.77	25.80	0.99	237.9
A	1.4593	31.98	234.54	4.16	81.84	29.64	2.80	24.91	.83	237.3
B	1.4593	33.45	235.72	4.31	83.30	29.50	2.67	24.94	.75	238.1
C	1.4598	36.16	233.16	4.38	82.48	30.35	2.31	25.79	.72	238.7

SUMMARY AND CONCLUSIONS

The milk fat produced by three groups of cows during the feeding of different grain mixtures has been studied. The conclusions that may be drawn from this work are:

Milk fats produced during the feeding of grain mixtures so prepared that approximately half the protein content is supplied by (1) cottonseed meal, (2) linseed meal, and (3) ground soybeans differ to some extent in some of their physical and chemical characteristics.

Milk fats produced during the feeding of a grain mixture so prepared that half its protein is from ground soybeans, show on an average a higher index of refraction and iodine number, slightly higher mean molecular weight, and lower saponification and Polenske num-

bers than those produced during the feeding of the other grain mixtures used in this work.

The differences between the fats produced by cows fed the grain mixtures used in this investigation do not appear to be large enough to be of other than scientific interest.

LITERATURE CITED

(1) AMBERGER, C.
1907. DER EINFLUSS DER FÜTTERUNG AUF DIE ZUSAMMENSETZUNG DES BUTTERFETTES. Ztschr. Untersuch. Nahr. u. Genussmtl. 13: 614–621.

(2) ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS.
1925. OFFICIAL AND TENTATIVE METHODS OF ANALYSIS. COMPILED BY THE COMMITTEE ON EDITING METHODS OF ANALYSIS. REVISED TO JULY 1, 1924. Ed. 2, 535 p., illus. Washington, D. C.

(3) BOLTON, E. R.
1928. OILS, FATS, AND FATTY FOODS, THEIR PRACTICAL EXAMINATION; A HANDBOOK FOR THE USE OF ANALYTICAL AND TECHNICAL CHEMISTS AND MANUFACTURERS . . . 416 p., illus. Philadelphia.

(4) BOES, J., and WEYLAND, H.
1915. ZUR KENNTNIS DES EINFLUSSES DER ZUCKERRÜBENFÜTTERUNG AUF DIE ZUSAMMENSETZUNG DES MILCHFETTES. Ztschr. Untersuch. Nahr. u. Genussmtl. 29: 473–475.

(5) CRANFIELD, H. T.
1911. THE EFFECT OF FEEDING WITH COCOANUT CAKE AND LINSEED CAKE ON THE COMPOSITION OF BUTTER-FAT. Analyst 36: [445]–449, illus.

(6) ——— and TAYLOR, M. G. D.
1915. THE EFFECT OF FEEDING ON THE COMPOSITION OF MILK AND BUTTER: LINSEED CAKE AND HEMPSEED CAKE. Analyst 40: 433–439, illus.

(7) ECKLES, C. H., and PALMER, L. S.
1916. EFFECTS OF FEEDING COTTONSEED PRODUCTS ON THE COMPOSITION AND PROPERTIES OF BUTTER. INFLUENCE OF THE CHARACTER OF THE RATION AND QUANTITY OF COTTONSEED PRODUCTS. Missouri Agr. Expt. Sta. Research Bul. 27, 44 p., illus.

(8) FRITZSCHE, M.
1909. BEITRAG ZUR KENNTNIS DER ZUSAMMENSETZUNG DES BUTTERFETTES BEI RÜBENBLATTFÜTTERUNG. Ztschr. Untersuch. Nahr. u. Genussmtl. 17: 533–536.

(9) GEISLER, J. F.
1926. THE EFFECT OF COTTONSEED FEEDING ON BUTTERFAT. Jour. Oil & Fat Indus. 3: 115–118.

(10) KIEFERLE, F.
1923. DER EINFLUSS DER VERFÜTTERUNG VON GARFÜTTER AUF DIE ZUSAMMENSETZUNG DES MILCHFETTES. Milchw. Forsch. 1: [2]–14.

(11) LEACH, A. E.
1920. FOOD INSPECTION AND ANALYSIS, FOR THE USE OF PUBLIC ANALYSTS, HEALTH OFFICERS, SANITARY CHEMISTS, AND FOOD ECONOMISTS. Rev. and enl. by A. L. Winton. Ed. 4, 1090 p., illus. New York.

(12) LINDSEY, J. B., HOLLAND, E. B., and SMITH, P. H.
1909. EFFECT OF SOYBEAN OIL UPON THE COMPOSITION OF MILK AND BUTTERFAT, AND UPON THE CONSISTENCY OR BODY OF BUTTER. Mass. Agr. Expt. Sta. Rpt. 21 (pt. 2): 66–110.

(13) LÜHRIG, H., HEPNER, A., and BLAU, G.
1909. UEBER DIE BEEINFLUSSUNG DER ZUSAMMENSETZUNG DES BUTTERFETTES DURCH RÜBEBLATTFÜTTERUNG. Pharm. Zentralhalle 50: [275]–282.

(14) SIEGFELD, M.
1907. DER EINFLUSS DER VERFÜTTERUNG VON RÜBENBLÄTTERN UND RÜBENKÖPFEN AUF DIE ZUSAMMENSETZUNG DES BUTTERFETTES. Ztschr. Untersuch. Nahr. u. Genussmtl. 13: [513]–524.

(15) ———
1909. DIE ZUSAMMENSETZUNG DES BUTTERFETTES BEI RÜBENBLATTFÜTTERUNG. Ztschr. Untersuch. Nahr. u. Genussmtl. 17: [177]–181.

(16) SMITH, F. H., WELLS, C. A., and EWING, P. V.
1916. THE CHANGES IN COMPOSITION OF BUTTERFAT PRODUCED BY FEEDING COTTONSEED OIL. Ga. Agr. Expt. Sta. Bul. 122, p. [95]–111.
(17) ZAITSCHEK, A.
1911. ÜBER DEN EINFLUSS DER FUTTERMITTEL AUF DIE ZUSAMMENSETZUNG DES MILCHFETTES. Landw. Vers. Sta. 74: [250]–262.

THE MIGRATION OF BACILLUS AMYLOVORUS IN THE TISSUE OF THE QUINCE[1]

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HISTORICAL REVIEW

The fire-blight organism, *Bacillus amylovorus* (Burr.) Trev., is of considerable economic importance because of the disease it produces on three hosts—apple, pear, and quince. A study of the comparative cytological reactions of host and parasite for these three species is of particular biological interest.

Nixon (*5, p. 9*)[3] first described the annual life cycle of *Bacillus amylovorus* in apple tissue. According to this author, the life cycle consists of two stages. The first stage is characterized by the formation of zoogloeae in which the bacteria migrate intercellularly, with the formation of schizogenous cavities "by toxic plasmolysis and crushing." The regions invaded by the bacteria during this stage are described as follows:

> * * * the "optimum path" of migration is confined to the intercellular spaces of a zone of cells in the inner cortex * * *. From the "optimum region" the invasion of adjacent, less favorable tissues, may follow * * *. The last tissues to be invaded are the cambium, the xylem and pith, and these are rarely seriously attacked.

In the second or "pseudo-fructification" stage the bacteria become smaller and invade the cells by dissolving the cell wall, thus forming lysigenous cavities. The second stage culminates in the formation of cysts within the cells, in which condition the organism passes the winter.

Haber (*2, p. 10*) found that under artificial conditions young apple leaves may be the portal of infection; that the bacteria migrate in the form of zoogloeae in the intercellular spaces of the vein parenchyma and spongy mesophyll of the leaf, and that death of the tissues is caused by "plasmolysis of the protoplast, the collapse of cell walls, and the separation of contiguous cell walls to form schizogenous cavities."

The results of Gibbons's[4] investigation concerning the invasion of the organism and its effect on the host tissue in pear paralleled Nixon's results with apple. Tullis (*7*) also corroborated Nixon's work as to the general features of the migration of the organism.

Rosen (*6*), in studying the invasion of the floral structures and petioles of pear and the stems of apple and pear, also reported migration as taking place in the spaces between the cortical cells. The middle lamellae and the cell walls of these cells are broken apart by

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[3] Reference is made by number (italic) to Literature Cited, p. 63.

[4] GIBBONS, F. P. THE MIGRATION OF BACILLUS AMYLOVORUS IN PEAR TISSUE. (Unpublished master's thesis, Pennsylvania State College.)

chemical dissolution with no signs of pressure observable on the cells. This dissolution is noted as occurring ahead of the invading mass of bacteria. The movement of the mass of bacteria in the intercellular spaces is considered "a passive one engendered by the accretion of great numbers of bacteria rather than an active pseudopodlike movement * * *." Rosen reports that all the stem tissues are later invaded and that death of the host is attributable to the formation of cavities by dissolution, particularly in the phloem and cambium, rather than to toxic products secreted by the pathogene.

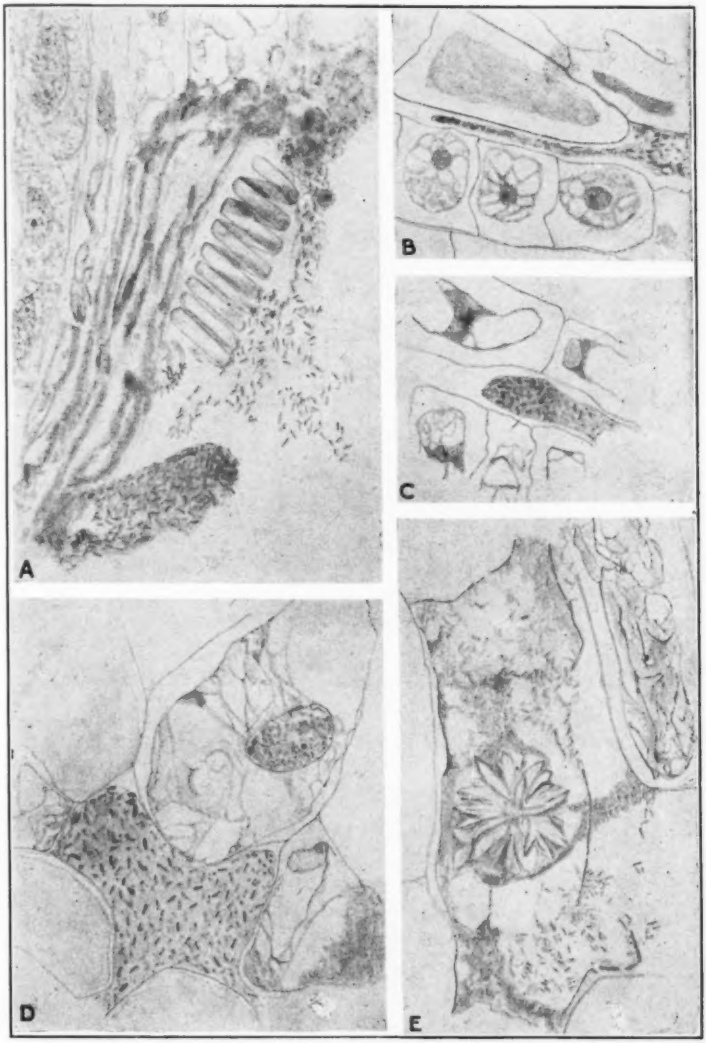
A review of the literature reveals no reference to any microscopic studies of the invasion of the tissues of the quince (*Cydonia vulgaris* Pers.) by this organism.

METHODS

The research presented in this paper was begun at the Pennsylvania State College in the spring of 1925, when a series of inoculations was made on young quince trees growing in the college greenhouse. A pure culture of *Bacillus amylovorus* had been secured previously by isolating the bacteria from blight cankers that had been brought into the laboratory and kept in a moist chamber until the gummy exudate characteristic of this organism appeared. The culture was grown on Lima bean agar and its pathogenicity proved by inoculation of quince trees and reisolation of the organism. Inoculations were made with a sharp laboratory needle introduced at the growing tip of the twig, the puncture being made entirely through the twig. Sections were taken after ½, 1, 1½, 2, 4, 6, 8, 10, 12, 16, 18, 24, and 48 hours, fixed in Flemming's weak solution, and embedded in paraffin by the usual method. In the spring of 1927 a duplicate series of inoculations was made on quince trees growing in the college orchard. The method of inoculating and embedding was the same as that used in the earlier experiments except that sections were taken up to 142 hours after inoculation and were fixed in Flemming's weak, Petrunkevitch's, and alcohol-formalin-acetic fixing fluids. Sections were cut 9μ to 11μ thick and stained with Flemming's triple stain.

OBSERVATIONS

Microscopic examination of the early stages following inoculation showed the bacteria lying along the edge of the puncture, where they had multiplied rapidly in the broken remains of the injured cells. Invasion of the uninjured tissues was found to have taken place in a narrow cylindrical area in the inner cortex extending around the stem about 10 cells inward from the epidermis and several cells outward from the phloem region. In this area the bacteria were found in zoogloeal masses invading the intercellular spaces in all directions from the puncture, though more rapidly in a longitudinal than in a tangential direction. Radially the intercellular spaces were occupied only in a layer three to five cells wide. No invasion beyond the puncture was observed one-half hour after inoculation, although at that time large masses of bacteria were present in the puncture. (Pl. 1, A.) After 4 hours the bacteria had reached a distance of about 0.037 mm from the puncture (pl. 1, B), and after 12 hours they had reached a distance of 0.5 mm (pl. 1, C). At this stage none of the cells in the infected area were occupied nor were the cell contents in any way injured, except for a slight plasmolysis.



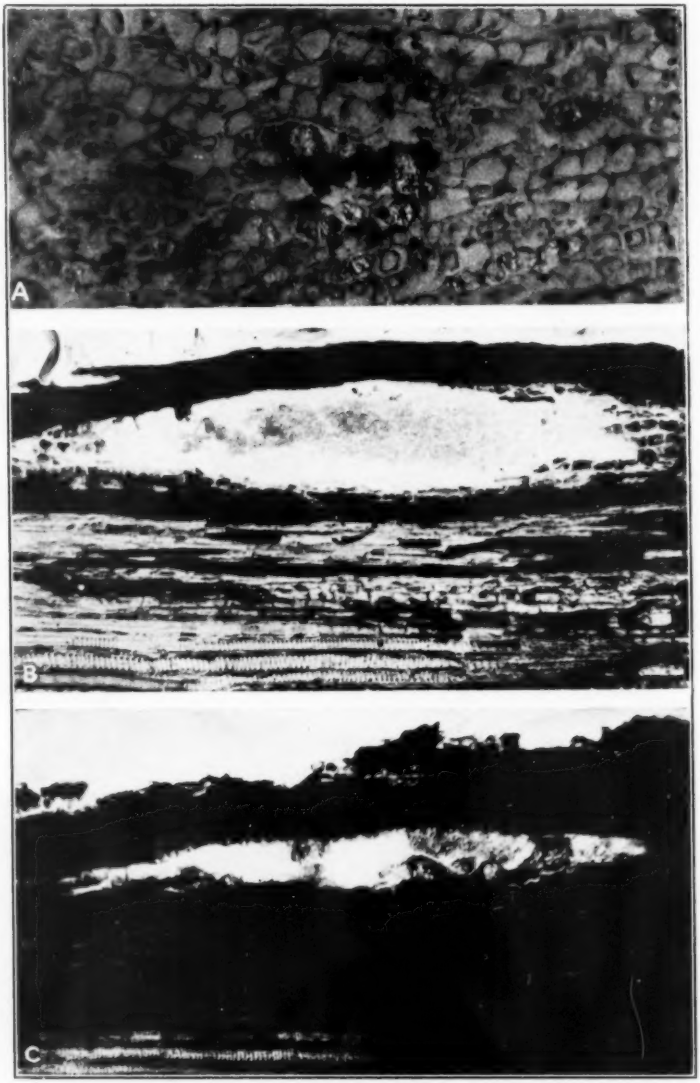
A.—Bacteria in the puncture, one-half hour after inoculation. The broken remains of cells, including a xylem vessel, are present. × about 1,750.

B.—Zoogloeal mass formed at edge of puncture invading intercellular spaces of inner cortical region, four hours after inoculation. × about 1,000.

C.—Tip of zoogloea, 12 hours after inoculation. × about 1,250.

D.—Bacteria occupying a space between cortical cells with evidence of slight pressure and splitting of cell walls, 42 hours after inoculation. × about 1,750.

E.—The beginning of lysigenous cavity formation by the dissolution of cell wall and protoplasm. The crystal in the cell is not attacked by the bacteria. × 1,000.



A.—The formation of a lysigenous cavity by the dissolution of adjacent cortical cells; 110 hours after inoculation at a distance of 2.3 cm from puncture. × about 185.

B.—An extremely large lysigenous cavity in the cortex; 66 hours after inoculation adjacent to puncture. All the cortical cells are dead, but there is no noticeable effect on phloem, cambium, xylem, or pith cells. × about 185.

C.—Mostly tangential section of cortex showing death to all cells; 142 hours after inoculation adjacent to puncture. × about 185.

After 42 hours the bacteria had traveled a distance of about 1.5 mm from the point of entrance and had formed numerous, though not large, schizogenous cavities. (Pl. 1, D). Certain cells were split apart at the middle lamella, and the cell walls were slightly invaginated. Also, during this time and in the same region, a few cells were seen to be entirely filled with bacteria. These cells retained their normal outline, while the protoplast was not destroyed but was pushed to one end of the cell, where it became an almost or quite homogeneous mass. Although the complete life cycle of *Bacillus amylovorus* is not being considered here, this condition corresponds closely with the early stages shown by Nixon in apple in which the bacteria multiply rapidly within the lumen of a cell, eventually rounding up to form a cystlike body that is the overwintering form of the organism.

After a time the organism apparently changes its method of invasion and migrates without regard for cells or intercellular spaces. In this stage cell walls and protoplasts alike succumb to the invading horde of bacteria. Cells are entirely broken down, so that no indication of their previous existence remains. The bacteria are now arranged in thin radiating strands in the lysigenous cavities thus formed, their arrangement suggesting that they have utilized the cell wall, nucleus, and cytoplasm for food and have thus formed a strand of bacteria where once there was a strand of cytoplasm or a cell wall. This takes place within 96 hours after inoculation, when the bacteria have traveled a distance of 1 to 1.5 cm from the puncture, and continues until the entire inner cortical region is broken down, the cells shrunken, and their protoplasts entirely disorganized. (Pls. 1, E, and 2, A, B, C.) This is the condition at 142 hours after inoculation, when the invasion has extended longitudinally from the puncture at least 5 cm. Stages later than 142 hours after inoculation have not been studied.

DISCUSSION

The results secured in the present study agree with those of Nixon (*5*) and Haber (*2*) in their work with apple and of Gibbons [5] with pear, thus showing that there is to be found no essential difference in method of migration in any of the three economic hosts of this parasite. These studies also show essential agreement with the work of Hill with *Bacterium tumefaciens* in tomato (*3*) and *Bact. tabacum* in tobacco (*4*) and of Beach with *Bact. vignae* in Lima bean (*1*), so far as the method of migration of the bacterial pathogene is concerned.

The zoogloeal mass invaded the tissues at an average rate of 9μ per hour for the first 4 hours, 42μ per hour for the first 12 hours, 36μ per hour for the first 42 hours, 156μ per hour for the first 96 hours, and 352μ per hour for 142 hours. These figures represent only one to several measurements in each case. Although the figures are open to error because of the small number of measurements and because of the difficulty of determining the exact extent of the invasion, a marked difference in rate is shown between the earlier and later stages. Thus, for the 38 hours from the 4 to the 42 hour period after inoculation, the average rate of migration was 38μ per hour. During the next 54 hours the average rate had increased to

[5] GIBBONS, F. P. Op. cit.

about 250μ per hour, and the average for the next 46 hours was 761μ per hour. Haber found that the zoogloeae in apple leaves traveled a distance of 0.5715 mm in 12 hours and had reached a distance of 1.5 mm from the puncture after 24 hours. This is an average rate of 47.6μ per hour for the first 12 hours and 62.5μ per hour for the first 24 hours. Nixon reports a migration of 3 or 4 inches in 24 to 48 hours after inoculation in apple stems. Four inches in 48 hours represents a rate of 2,115μ per hour. It would seem desirable that further work be done with the different hosts under controlled conditions of temperature, humidity, age, and rate of growth of host, etc., to determine, if possible, the factors responsible for such a wide range in the rate of migration.

Nixon found that the region of intercellular migration in apple may extend entirely around the stem and, longitudinally, may involve the entire twig and adjacent limb, and under optimum conditions may extend several feet. In this study the bacteria were found entering the cells of quince within a distance of 1.5 cm from the point of inoculation, and were not found invading the entire circumference of quince stems through the intercellular spaces.

During this intercellular migration some cells in the path of the invading mass of bacteria become separated along the line of the middle lamella. How this separation takes place is still problematical. Two possibilities, however, present themselves as primary factors—either the pressure from the mass of bacteria is great enough to separate the cells or some solvent action of the products of the organism causes the dissolution of the middle layers of the cell wall. Slight evidence of pressure exerted upon the cell is present in the form of indentations in the cell wall. (Pl. 1, D.) Since, however, the cells all through the region of intercellular migration and schizogenous cavity formation are slightly plasmolyzed, it is evident that the cell turgor in these cells is quite low or is, perhaps, entirely lacking. Thus very little pressure would need to be exerted by the bacterial mass to cause invagination of the cell wall. The evidence, then, indicates that only a very slight amount of mechanical pressure is exerted by the invading mass of bacteria. This leads to the conclusion that the cells are split apart by some solvent action of the bacteria.

Many stages in the dissolution and disorganization of cells resulting from bacterial activity were found. Plate 1, E, shows the bacteria at work in the destruction of the wall and contents of a single cell. In Plate 2, A, may be seen an early stage in the formation of a lysigenous cavity by the breaking down of adjacent cells. Advanced stages of these processes are shown in Plate 2, B and C, where extensive cavities have been formed by the total disintegration of several layers of cells in the most susceptible region in the inner cortex. The lysigneous cavity thus formed (pl. 2, A) measures 80μ by 425μ. By examining serial sections this cavity was found to extend in a tangential direction around the stem at least 150μ, each section showing the cavity occupied by a mass of bacteria. The preparations contained many such cavities, each showing the bacteria in good condition. This would seem to contradict the statements of Tullis (*7*) and Rosen (*6*) as to the inadequacy of stained paraffin sections for preserving the correct condition and relation of *Bacillus amylovorus* and its host.

There seems to be no reason to doubt that the cell walls and contents are acted upon by growth products of the bacteria and broken

down just as other food materials are broken down by other bacteria. The finer details of the dissolution of the host cells and the exact nature of the method by which the bacteria produce the dissolution are not within the scope of this investigation. Far more important are the reasons for the death of all the tissues, even those not directly attacked by the organism, by the time the organism has been active in the stem for 100 hours. The organism was not found in any tissues of young quince stems except the narrow cortical region previously described. In spite of this, tissues, including phloem, cambium, and pith, are definitely shown to be dead adjacent to the area of cortical invasion. (Pl. 2, C.)

These results are in contrast to those reported by Rosen (*6*), who states that in apple stems "* * * by far the most serious effects on the infected twig or limb result * * * from invasion of the phloem and cambium. It is the destruction of the latter and not the cortex which results in the death of the twig or limb." Rosen states further (*6, p. 64*) that "* * * the evidence is indeed substantial for the assumption that diffusible toxic products are not produced by *B. amylovorus*." If Rosen's results are correct, then we are confronted by the fact that the same organism must operate in an entirely different manner to produce the results here recorded for quince. Some tissues of quince stems are killed without being invaded by the organism. The tissues that are invaded are not those directly concerned with either growth or food conduction. The destruction of the tissues invaded is not sufficient to explain the death of the entire twig. Therefore, the evidence is substantial for assuming that diffusible toxic products of *Bacillus amylovorus* are responsible for the death of the stem tissues of quince not invaded by the organism.

SUMMARY

Bacillus amylovorus migrates through the intercellular spaces of the inner cortex of quince in the form of zoogleae.

During this invasion schizogenous cavities are produced in quince in a manner similar to that previously reported by Nixon in apple.

Intracellular invasion of the cortex, involving formation of lysigenous cavities, occurs within 96 hours after inoculation.

Death of all the stem tissues occurs within 100 hours after intercellular invasion and within 48 hours after intracellular invasion of the adjacent cortex, although during this time the organism is present only in the cortex.

LITERATURE CITED

(1) Beach, W. S.
1928. The relation of bacterium vignae to the tissues of lima bean. Penn. Agr. Expt. Sta. Bul. 226, 15 p., illus.

(2) Haber, J. M.
1928. The relationship between bacillus amylovorus and leaf tissues of the apple. Penn. Agr. Expt. Sta. Bul. 228, 15 p., illus.

(3) Hill, J. B.
1928. The migration of bacterium tumefaciens in the tissue of tomato plants. Phytopathology 18: 553–564, illus.

(4) ———
1929. Migration of bacterium tabacum through the leaf tissues of nicotiana tabacum. (Abstract) Phytopathology 19: 97.

(5) NIXON, E. L.
1927. THE MIGRATION OF BACILLUS AMYLOVORUS IN APPLE TISSUE AND ITS EFFECT ON THE HOST CELLS. Penn. Agr. Expt. Sta. Bul. 212, 16 p., illus.
(6) ROSEN, H. R.
1929. THE LIFE HISTORY OF THE FIRE BLIGHT PATHOGEN, BACILLUS AMYLOVORUS, AS RELATED TO THE MEANS OF OVERWINTERING AND DISSEMINATION. Ark. Agr. Expt. Sta. Bul. 244, 96 p., illus.
(7) TULLIS, E. C.
1929. STUDIES ON THE OVERWINTERING AND MODES OF INFECTION OF THE FIRE BLIGHT ORGANISM. Mich. Agr. Expt. Sta. Tech. Bul. 97, 32 p., illus.

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